

REPORT DOCUMENTATION PAGE		Form Approved OMB No. 0704-0188
<small>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Project (0704-0188), Washington, DC 20503.</small>		
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE 14.11.95	3. REPORT TYPE AND DATES COVERED 22 August, 1994 to 31 October 1995
4. TITLE AND SUBTITLE <i>Correlation and Gradients Characteristic Parameters in Europe</i>		5. FUNDING NUMBERS N68171-94-C-9119
6. AUTHOR(S) <i>Ehud Heyman Elene E. Tsedilina</i>		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <i>Ramat -University Authority for Applied Research and Industrial Development Ltd., P.O.B. 39296, Tel-Aviv 61392, Israel</i>		8. PERFORMING ORGANIZATION REPORT NUMBER 731/F (final)
9. SPONSORING, MONITORING AGENCY NAME(S) AND ADDRESS(ES) <i>Naval Regional Contracting Center Detachment London, Block 2, Wing 11, Due Complex, Eastcote Road, Ruislip, Middx, HA4 8B5, England</i>		10. SPONSORING, MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES DISTRIBUTION UNLIMITED		
12a. DISTRIBUTION/AVAILABILITY STATEMENT APPROVED FOR PUBLIC RELEASE Approved for public release Distribution Unlimited		12b. DISTRIBUTION CODE
13. ABSTRACT (Maximum 200 words) Diurnal and seasonal regularities of spread-F and scattered F-traces have been evaluated for one year of high solar activity at midlatitudes by processing and scaling about 900 color ionograms written in ARTIST system (1991, sounding station Roquetes, Spain). The relationship of spread-F and scattering in F-layer with magnetic disturbances is considered. Effect of terminator on the spread-F and scattering clearly defined. Occurrence of blackouts is presented. Comparison of IRI-90 parameters with measured ionospheric parameters at three midlatitude ionospheric stations in Europe was examined.		
KEY WORDS Spread-F, scattering, irregularities, ionospheric plasma, vertical ionograms sounding station, Digisondes, ARTIST, magnetic activity, terminator, seasonal occurrence, magnetic storm, blackouts, IRI-90, ionospheric parameters, indexes.		15. NUMBER OF PAGES
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED

NSN 75-0-01-280-3500

19960122 123

DTIC QUALITY INSPECTED

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

CORRELATION AND GRADIENT CHARACTERISTICS OF IONOSPHERIC PARAMETERS IN EUROPE

Final Technical Report

by

E. Heyman
E. E. Tsedilina
O. V. Weitsman

November 1995

United States Army

EUROPEAN RESEARCH OFFICE OF THE U.S. ARMY

London England

CONTRACT NUMBER N68171-94-C-9119

RAMOT BY TEL AVIV UNIVERSITY
DEPARTMENT OF PHYSICAL ELECTRONICS,
FACULTY OF ENGINEERING

Approved for Public Release; distribution unlimited

Acknowledgments

This report has been done by Dr. Tsedilina and Dr. Weitsman with appreciating help of Prof. E. Heyman

CONTENT

I. SPREAD - F AND SCATTERED TRACES	3
1. Introduction	3
2. Vertical ionograms and their processing for 1991	7
3. The method of scaling of spread-F and scattered traces	8
4. Annual, diurnal and seasonal dependencies of scattering and spread-F in F-layer	9
5. Occurrence of spread-F	11
6. Effect of terminator	12
7. Connection with magnetic activity	14
a) Correlations of Ap, Kp and spread-F indexes	14
b) Dst and spread-F indexes	15
c) Annual appearance of spread-F in connection with the variations of Kp and Dst indexes	15
8. Analysis of magnetic storm of 24-26 March 1991	16
9. Blackouts	18
II. COMPARISON OF THE IRI PARAMETERS WITH MEASURED IONOSPHERIC PARAMETERS	19
III. CONCLUSIONS AND RECOMMENDATIONS	19
IV. REFERENCES	23
V. APPENDIX	28

I. SPREAD-F AND SCATTERED TRACES

1. INTRODUCTION

The phenomenon of the spread of signals on the ionospheric vertical ionograms, or diffuse broadening of traces in some frequency (frequency spread) or height (range spread) intervals has been studied extensively over the last few decades. Spread of signals strongly influences the propagation of VHF and HF radio waves and the operation work of modern sophisticated radio systems. It is known that the main reason of signal spread is scattering of radio waves by ionospheric irregularities or acoustic-gravity waves [1-6]. The same reason is due to appearance of amplitude scintillations of radio stars [7] and emitted radio satellite signals [8-10]. The role of acoustic-gravity waves or large and medium-scale structures, and small irregularities of different sizes and elongation in the formation of the spread of traces on the ionograms, or of the rate of amplitude scintillations still has not been fully understood [1-3,13,15].

We consider spread-F or scattered signals at midlatitudinal ionospheric sounding station Roquetes, Spain (40° N; $0,6^{\circ}$ E) for the 1991 year of high solar activity. Although spread-F have been investigated for 30-40 last years, its appearance regularities, relations with other geophysical phenomenon and the reasons of its arising have not received properly understanding. Before we consider our results of spread-F study at the European station we briefly conceive the properties of spread-F, known at midlatitude region.

According to references [11-13], spread-F and scintillations appear in this region rather seldom in comparison with highlatitude and lowlatitude regions, where they were studied very active during last years. Meanwhile the number of measurements, observations and studies of irregularities and associating phenomenon, those, as spread-F and scintillations, in this particular region is very limited [14-19].

The basic irregularity properties (or spread-F or scintillation properties) appear to be following:

1. Long - time variation

The type of the connection with solar activity is not definite. According to [16, 19], solar cycle occurrence, in general, is inversely correlated with sunspot number. Thus, Bowman [20] obtained that averaged spread-F occurrence during sunspot minimum is 2-3 times greater than during sun-spot maximum for all months of 1963-1965 and 1957-1959 and is in accordance with equatorial F-spread occurrences. On the contrary, in [14, 21] relatively higher activity of scintillations and spread-F was obtained at sunspot maximum. In [10] enhanced occurrence of scintillations was observed in response to increased solar activity. Any noticeable variations of spread-F occurrence were not received during solar cycle from 1958 to 1966 in Alma-Ata [12].

2. Seasonal variation

Seasonal variation is also not certain. According to [12,16] maximum of occurrence is usually observed in winter or summer solstices or in summer, or for some years in equinoxes or winter [21]. According to [14] maximum is observed in spring or autumn equinoxes. This variation appears to be dependent on magnetic activity in the months considered and on the longitude location of the observation station. Thus, in [19] were picked up two types of spread-F: equinoctial type during high solar activity (seasonal activity maximum in equinoxes) and summer type (maximum of seasonal activity in summer) during low solar activity.

3. Diurnal variation

Strong maximum of spread-F and scintillation occurrence is at nighttime. Sometimes it is observed at pre-midnight hours and sometimes at post-midnight [14,16,19,20]. During the day-time occurrence of irregularities is low, but not negligible.

4. Variation with magnetic activity

Dependence on magnetic activity is rather complicate. It was received in [9,18] that a correlation between scintillations and magnetic activity at midlatitudes, in general, is

negative. A positive correlation between scintillations and Kp indexes in winter, no correlation between scintillations and Kp indexes in equinoxes, and negative correlation in summer was obtained in [14]. The delayed occurrence of midlatitude spread-F following times of high AE magnetic indices was investigated in [33]. The results show that peaks in F spread occurrences follow enhanced geomagnetic activity in the sunrise period, with approximately 24-hour intervals.

5. Terminator effect

The connection of scintillations with sunset and sunrise is indicated in [9,14]. In [14] abrupt increase of scintillations was observed just after sunset on the earth in summer months. In winter months such increase was not observed. Significant increase in spread-F just after local sunrise in winter was presented in [9]. The scintillation data do not appear to show this effect during the same time-periods.

6. Waves, spread-F and scintillations

The relationship of spread-F and scintillations with acoustic-gravity and magneto-gravity waves in the ionosphere has been investigated for the last decades very active [3,13,15,20,22,23]. The spread-F has been observed last years with more precision sounding techniques in the HF band. This gives the possibility to observe and study the fine structure of diffuse, duplicate and any other form's traces. Experiments show that waves as patterns in the TEC (total electron contents) are found to be accompanied by shot-period scintillations [24] and also by spread-F [25].

The spread-F appears often after the rise of F-layer and electron-density depletion. The last variations are connected with the AGW (acoustic-gravity waves) passage and negative magnetic storm effects in the ionosphere [26,27].

As a conclusion of these and other experimental facts, Bowman [15] discusses the idea that the formation and type of spread-F is connected with four different scale sizes: day and night large-scale (TIDs), medium-scale (height stratification), and small scale (weak quasi-horizontal (QH) patches) with field-aligned irregularities, embedded in the stratified regions.

7. Other results

During last years the appearance of spread-F and scintillations were studied for individual magnetic storms. As a result of this study the occurrence of the irregularities was supposed to be connected with variations as well as a rate and a direction of variations of electron density in the ionosphere, electric field and ring current [15, 28, 29].

In [30-31] ionospheric irregularities were observed by different methods simultaneously. The results of these observations show that very often irregularities are detected only by one experimental method and not detected by other methods. This fact has not yet received sufficient explanation.

Until recent time the theory of the irregularities and wave at midlatitudes has been not completed [5,32].

The mechanism of formation of F spread on the ionograms is not fully understood although some important ideas emerged. We will point out here that the amplitudes of spread-F signals in most cases are of the same order of value as non spread signals on the regular traces. Only some part of spread-F recordings has the spread signals by 10-20 dB less than undisturbed signals on the ionograms.

Many properties of the irregularities at midlatitudes show that they can appear due to convection flow of electron density from polar or equatorial and crest regions to midlatitude regions. In the same time, only convection connections with polar, equatorial and crest regions can not explain all the occurrence's properties of the irregularities at midlatitudes. Theoretical and experimental investigations in this particular field are still very important.

The most part of this Report introduces the results of study of spread-F and scattered traces on the vertical midlatitude ionograms for one year. We present the experimental data and its relationship with geophysical conditions.

The statistics of full blackouts for the same year is reported and its relationship with geophysical conditions is discussed.

The second small part of this Report deals with the comparison of main ionospheric parameters such as critical frequencies foF2 and foE in the International Reference Ionosphere Model IRI-1990 with measured parameters at midlatitude station.

2. VERTICAL IONOGRAMS AND THEIR PROCESSING FOR 1991

We worked with vertical ionograms obtained at the ionospheric sounding station Roquetes in Spain (40° N; 0,6° E) at hourly intervals in digital codes. They were received by the aids of computer program ARTIST [11], which outputs not only ionospheric ionogram but also scales many basic parameters of the ionogram. For quiet conditions ARTIST also gives the dependence of the distribution of electron concentration versus real height or the profile of electron concentration. Unlike the last programs [34, 35] ARTIST [11] formulates the ionospheric ionograms in terms of ASCII symbols, which were used for recognition of polarization, Doppler shift and angles of arrival of reflected from the ionosphere signals.

These codes and the format used in these ionograms did not allow us to view the ionogram on one computer screen. That is why for processing, studying and printing the ionograms, written in the ARTIST [11] codes, we used our computer program, that was published in the Final Report "Analysis of ionospheric parameters in Europe and creation of the prediction algorithm", Contract DAJA45-92-C0006, 1993. This program transfers each ionogram in color pixels on one computer screen, what makes possible processing and analyzing the ionograms from computer screen.

For the needs of the present processing we had to update our computer program. For instance, the general parameters of the ionosphere layers such as foF2, foF1, foE, foEs, MUF, M3000, h'F, h'F2, h'E, h'Es, fmin, fxF, fF, fE, that are determined by the ARTIST program, are presented now on the same computer screen and can be printed together with the ionogram. This program has now the much more convenient interface, and is more friendly to the user, than before.

The ionograms, that this program uses for processing, are now rewritten on the diskettes in archives' codes. As the result of this action the number of diskettes in use is decreased 10-15 times in comparison with the amount of previous diskettes with ARTIST [11] codes. Owing to all these improvements, the processing and analysis of the ionograms, become significantly easier. We performed a detailed analysis of color ionograms directly from computer screen.

We cannot present here examples of color ionograms with which we were working. The examples of the ionograms printed in black-white and in the scale, more merged than on computer screen, are given in APPENDIX, Fig. 1-9. These Figures show the ionograms with F spread and give evaluated indexes for F spread what are presented in Tables 1-11 in APPENDIX (see p. 3 below). One can see in Fig. 1-5 some mistakes in foF2, which makes the ARTIST program because ionograms have breaks in F-traces.

3. THE METHOD OF SCALING OF SPREAD - F AND SCATTERED TRACES

To reveal the scattered conditions of the signals on the ionograms or the spread of the F echoes, we evaluated the special indexes with points and letters. They describe the type of the F echo signals on the ionogram and sometime the whole picture -- the ionogram.

The evaluated indexes and letters in Tables 1-11 in Appendix, which describe the spread and disturbed F traces, are the next ones. Strong disturbed traces in F region with frequency spread are determined by the letters f, ff, and fff. For further calculations we put these letters into accordance with numerical points 4, 5, 6 that describe strong, very strong and very, very strong disturbed traces with frequency spread of signals. The letters ccc, cc, c with points 1, 2, 3 were used for determining the traces with very small, small and close to strong types of spread. Approximately the letters c, f, ff and fff describe the traces with frequency broadening and the echo's width equal to 0.5-0.8 MHz, 0.8-1.0 MHz, 1.0-1.5 MHz, 1.5-2 MHz. We used also evaluative letters such as B - for

absorbtion, S - for noises, w - for week signals, A - for breaks in traces, E - for covering F traces by repeating reflections from E region (from E, Es layers), T - for technical reasons of violations. These letters describe the state of F traces on the ionograms as it was recommended, for instance, in [36]. The dash means the absence of the ionogram or the F trace at the ionogram. The absence of the dash or indexes c, f, r means the normal echo without any disturbances. In this case only evaluated letters (B, E, S, W, A, T) can be present in the Tables.

All letters in Tables 1-11, describing the appearance of F spread (c, f, ff, fff, fr, cr), are enclosed in circles. It allows very easily to recognize spread-F occurrences during the year considered.

The results of processing approximately 9000 ionograms are presented here in Tables 1-11 in APPENDIX. The state of F traces in these Tables is given in evaluated letters. We used points (numbers) corresponding to these letters for subsequent calculations.

The findings of analysis of ionograms for one 1991 year of high solar activity are presented below.

4. ANNULAR, DIURNAL AND SEASONAL DEPENDENCIES OF SCATTERING AND SPREAD IN F-LAYER

The method of scaling of F traces on vertical ionospheric ionograms gives us the possibility to investigate the scattering of radio waves by the irregularities of electron concentration or waves in the F-layer (F1 and F2). This problem was studied in papers [37-39]. HF field strength of radio waves over long-distant paths has been analyzed for one solar cycle in these papers. It has been received, as a result of this study, that the additional to collision losses of energy exist in the night and twilight ionosphere. They also take place in the day-time but are less than in other times. These losses were connected with scattering of radio waves by ionospheric inhomogeneities.

Our indication of the state of all F-traces in accordance with the rate of scattering of the reflected signals on the ionograms (a scale with points 0, 1, 2, 3, 4, 5, 6...) allow us to study not only the spread-F but also the conditions of signal scattering in the ionosphere. We do not discuss here the reasons of scattering of signals on the ionograms, which are received by an ionosond with different phase time-delay. Dispersion of time-delay of signals with a particular emitted frequency can be produced by many factors, those as scattering on the irregularities and waves in the ionosphere, regular and irregular horizontal and height variations of electron density, movements in the ionosphere, polarization effects and so on.

The averaged hour indexes of scattering Sh are presented in Table 1. They were obtained using Tables 1-11 from APPENDIX by summarizing and averaging for each hour the number indexes Si for all days of each month: $Sh = \Sigma Si / N$, where N is a number of ionograms for considered hour and month, and ΣSi is the sum of indexes for all available ionograms. The months December and January were studied together because each one from these two months has a small number of ionograms.

One can see from Table 1 that averaged indexes Sh vary from 0.6 to 3.3 during 1991. This means that the indexes Sh or scattering conditions vary in 5.5 times. Indexes $Sh < 1$ correspond to very quiet conditions in the ionosphere. $Sh \approx 1$ conforms to quiet conditions with small disturbances. If $1.5 < Sh < 2.0$, strong disturbed conditions with large possibility of F spread take place, and $2 < Sh < 3.3$ indicates very strong disturbed conditions with spread-F.

Seasonal variations of Sh indexes are demonstrated in Fig. 1. First of all, there is seen the maximum of Sh varying approximately from 1.5 to 3 in dawn hours during all year. Index of scattering is minimum during day-time. The maximum of Sh index does not release so clear during sunset as the maximum during dawn. It stands out clearly only in spring. The variation of indexes in winter is very irregular unlike other seasons. An influence of the terminator on the index of scattering and spread is considered in details in part 6.

Table 1. Mean hour index of scattering Sh of F traces, Roquetes, Spain, 1991

Hour\Mon	Dec -Jan	February	March	April	May	June	July	August	September	October	November	P
01	1.31	1.39	1.33	1.68	1.40	2.25	2.57	2.30	1.74	1.82	1.33	1.74
02	1.25	1.30	1.07	1.60	1.50	2.75	2.61	2.67	1.63	1.83	1.75	1.81
03	1.50	1.65	1.17	1.70	1.60	2.75	2.55	2.33	1.81	1.77	1.88	1.88
04	1.20	1.43	1.68	1.60	1.70	2.75	2.65	2.38	1.85	1.75	2.12	1.92
05	1.90	1.23	1.67	1.90	2.10	2.24	2.71	2.48	2.32	1.72	1.80	2.01
06	1.50	1.14	1.66	2.10	2.70	2.41	3.13	2.74	3.10	2.28	2.00	2.25
07	1.75	1.64	1.07	2.05	2.40	2.16	3.10	2.97	3.30	2.80	2.29	2.32
08	1.50	1.77	1.30	1.60	1.50	1.84	2.24	2.36	2.63	2.81	2.04	1.96
09	2.35	1.61	1.17	1.30	1.40	1.26	1.94	2.07	2.47	1.90	1.93	1.76
10	1.90	1.29	1.17	1.13	1.20	1.00	1.53	1.61	1.83	1.55	1.66	1.44
11	1.30	1.12	1.10	0.94	1.10	1.16	1.92	1.64	1.71	1.74	1.83	1.41
12	1.48	1.28	0.87	0.94	1.20	1.33	1.50	1.63	1.78	1.59	1.79	1.46
13	1.52	1.20	0.83	1.17	0.70	0.90	1.48	1.59	1.71	1.65	1.64	1.31
14	1.50	1.24	0.85	1.16	0.80	1.05	1.16	1.63	1.83	1.71	1.79	1.34
15	1.86	1.16	0.97	1.28	0.90	0.75	1.48	1.65	1.89	1.97	1.86	1.43
16	2.11	1.28	1.00	1.10	0.80	1.31	1.64	1.75	2.00	2.03	1.68	1.52
17	1.35	1.04	1.07	1.80	1.30	1.61	2.15	2.10	2.07	1.97	1.81	1.66
18	0.84	0.60	1.04	1.95	1.80	1.76	2.38	2.18	2.03	1.96	1.64	1.65
19	1.01	1.32	0.75	1.40	1.60	1.86	2.25	1.86	2.03	1.96	1.25	1.57
20	1.02	1.12	0.73	1.25	1.30	1.26	1.92	1.85	1.86	1.93	1.77	1.46
21	1.81	0.83	1.07	1.20	1.07	1.80	2.11	2.11	1.67	1.84	1.12	1.51
22	1.45	1.12	1.00	1.10	1.20	1.86	2.43	2.38	1.83	1.81	1.61	1.62
23	1.25	0.83	0.90	1.25	1.50	2.24	2.31	2.41	1.57	1.93	1.76	1.63
24	1.38	0.67	1.13	1.26	1.70	1.97	2.46	2.31	1.54	1.87	1.48	1.62

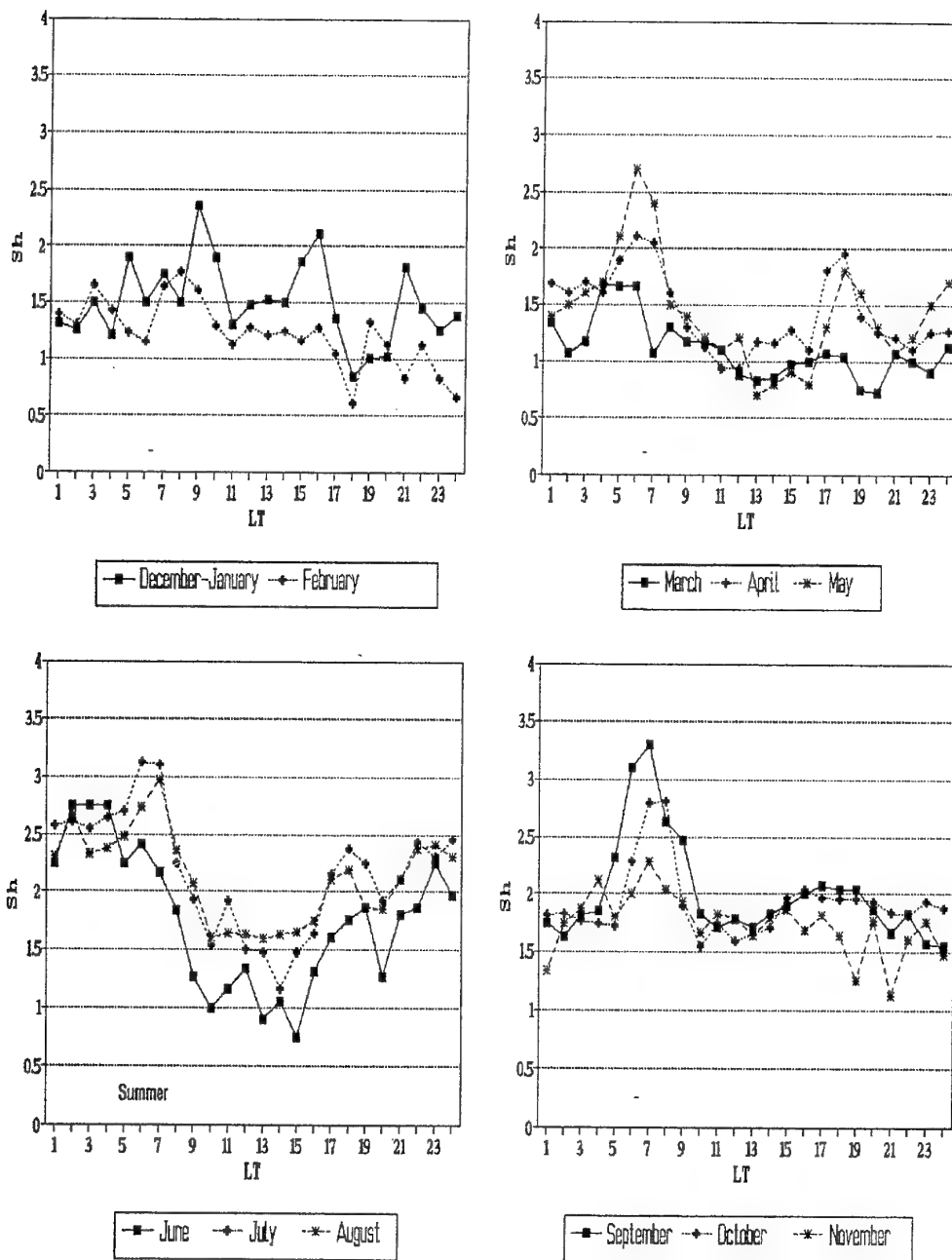


Fig. 1. Mean hour index of scattering Sh for the months of 1991, Roquetes, Spain, 1991.

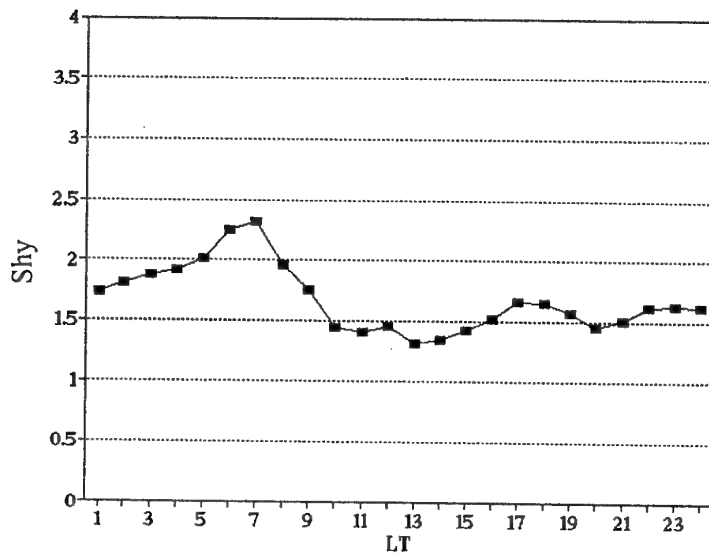


Fig. 2. Mean hour index of scattering Shy for 1991, Roquetes, Spain.

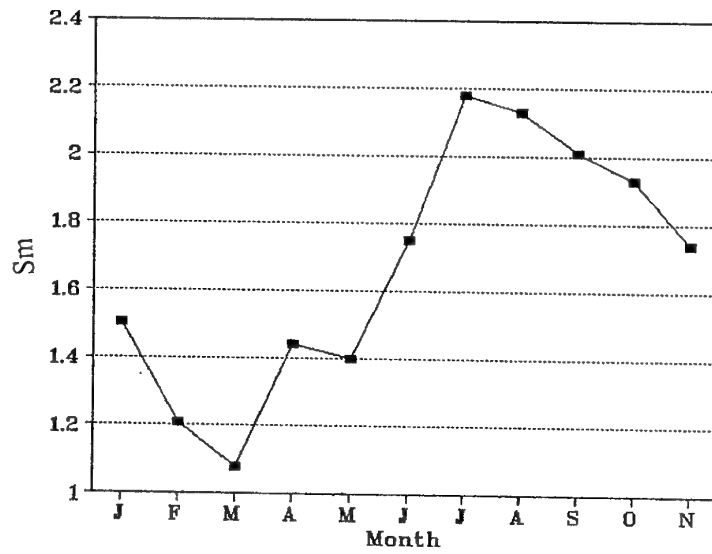


Fig. 3. Mean month index of scattering Sm, Roquetes, Spain, 1991.

Table 2. Mean month index of scattering Sm of F traces and full number Nd of strong disturbed traces (f, ff, fff, fr, r) for 1991; R-mean sunspot number, n - number of days with $\Sigma K_p > 28$.

Month	Dec-Jan	February	March	April	May	June	July	August	September	October	November
Sm	1.50	1.21	1.08	1.44	1.40	1.75	2.18	2.13	2.01	1.93	1.74
Nd	23	5	8	15	29	53	90	63	34	30	32
R	140.6	167.9	141.9	140.0	121.3	189.7	173.7	176.3	125.3	144.1	108.2
n	6	2	9	8	10	20	11	18	11	17	15

The magnitudes of the Sh indexes also point out at the probability of F-spread occurrence. For $Sh > 1.5$ probability of F spread is rather high (see text below).

Mean hour indexes Sh for one year (Shy) and each month (Sm) are shown in Fig. 2, 3 and Table 2. It is seen that year index Shy has a maximum of the order of 2.4 in morning hours and month index Sm has a maximum in July with magnitude 2.2. Minimal very low index Sm is observed in March with magnitude 1.15. Summer and autumn indexes are the largest ones. They vary from 1.8 to 2.2.

A total number Nd of cases with strong spread (Nd is the sum of cases with letters f, ff, fff, fr, r or numbers 4, 5, 6) and mean sun spot number R for each month of the year are given in Tab. 2 with Sm indexes. Rather good correlation is seen between Sm and Nd. Some correlation between indexes Sm and spot number R is observed only for summer and autumn months with higher solar and magnetic activities, and higher scattered and spread conditions. Such good correlations between solar activity and Sm indexes do not observe for minimum scattering and spread in February and March when magnetic field was more quiet.

These results about scattered signals on the vertical ionograms are in a good accordance with the results of [37-39] where scattering conditions in the ionosphere over long distant paths were investigated.

5. OCCURRENCE OF THE F SPREAD

Mean hour probability Ps of spread-F occurrence is introduced in Table 3. Here $Ps = N_c / N$, where N is a full number of ionogram with F traces for considered hour and month, N_c is the sum of number of cases with letters c, f, ff, fff, r or points 3, 4, 5, 6,... Thus, N_c represents a number of ionograms with spread-F. It is seen from Table 3 that probability Ps changes from zero to 90 %. Most quiet months are March and February, most disturbed period is from June to September. Only two cases of F spread were observed from 09 to 23 LT for the whole March. On the contrary, F spread was

Table 3. Probability $P_s = (N_c / N) \times 100\%$, N-number of days, Nc- Number of cases c, f, ff, fff, r, Roquetes, Spain, 1991.

Hour/Mon	Dec-Jan	February	March	April	May	June	July	August	September	October	November
1	10.0	13.0	6.7	11.0	13.0	46.0	43.0	40.0	19.0	21.0	17.0
2	20.0	13.0	3.3	22.0	14.0	54.0	64.0	57.0	7.4	20.7	29.0
3	20.0	17.0	6.9	11.0	17.0	54.0	48.0	50.0	19.0	20.0	29.0
4	16.0	13.0	21.0	22.0	20.0	50.0	50.0	34.0	30.0	25.0	40.0
5	20.0	4.5	13.0	22.0	33.0	38.0	54.0	52.0	32.0	24.0	28.0
6	16.0	1.5	14.0	44.0	55.0	41.0	80.0	56.0	86.0	41.0	35.0
7	22.0	4.5	3.6	52.0	43.0	32.0	76.0	66.0	90.0	63.0	32.0
8	17.0	18.0	3.7	17.0	17.0	32.0	24.0	32.0	67.0	65.0	39.0
9	44.0	4.3	0.0	5.5	9.7	5.3	21.0	19.0	47.0	20.0	7.4
10	11.0	8.3	0.0	6.3	7.4	5.9	12.0	7.1	17.0	3.4	10.3
11	5.0	4.2	0.0	5.9	0.0	0.0	17.0	12.0	7.1	6.8	10.3
12	5.0	4.0	0.0	5.9	8.0	0.0	17.0	11.0	7.4	0.0	7.1
13	5.0	4.0	0.0	5.5	0.0	0.0	19.0	6.9	14.0	0.0	7.1
14	5.0	4.0	0.0	11.0	3.6	5.3	4.0	17.0	14.0	6.8	3.5
15	20.0	4.0	0.0	5.5	3.4	0.0	16.0	6.5	7.1	9.7	7.1
16	20.0	0.0	0.0	5.0	7.0	11.5	11.0	7.1	10.7	3.2	0.0
17	5.0	8.0	0.0	20.0	3.5	10.6	35.0	13.0	3.6	0.0	3.8
18	5.0	4.0	0.0	30.0	17.0	24.0	45.0	14.0	6.9	7.4	8.0
19	6.0	0.0	0.0	5.0	10.1	27.6	32.0	3.6	6.7	17.0	10.0
20	16.0	0.0	0.0	5.0	7.1	3.7	32.0	7.7	3.4	24.0	19.0
21	26.0	0.0	0.0	0.0	3.7	13.0	38.0	26.0	3.3	19.0	16.0
22	16.0	8.0	0.0	0.0	3.4	17.0	43.0	42.0	21.0	26.0	19.0
23	16.0	0.0	6.7	5.0	14.0	41.0	38.0	44.0	7.1	17.0	20.0
24	24.0	0.0	6.7	5.0	26.0	31.0	36.0	48.0	18.0	27.0	16.0

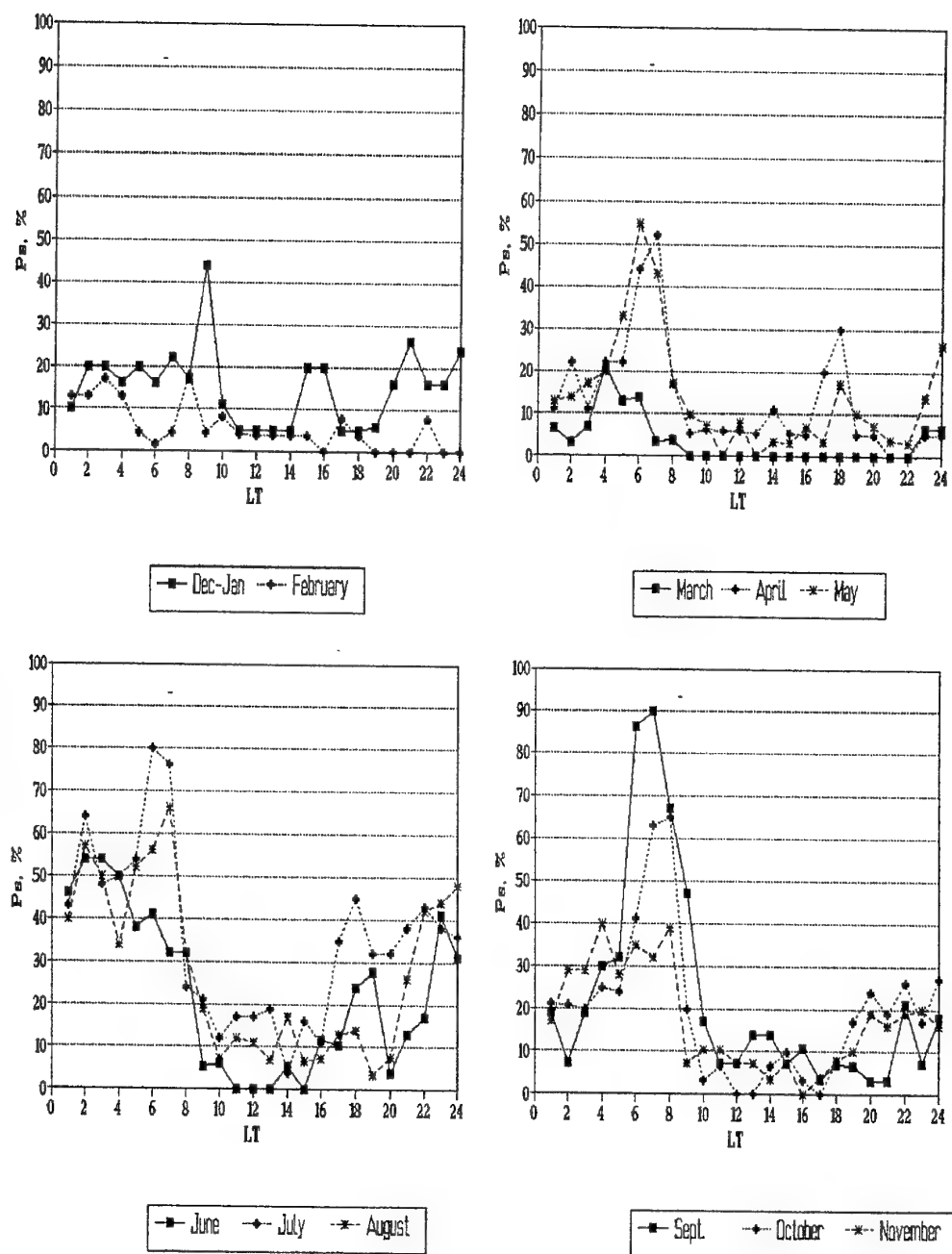


Fig. 4. Season probability P_s of spread-F occurrence; Roquetes, Spain, 1991.

Table 4. Number Nd of F traces with strong spread (f, ff, fff, fr, r) ; Roquetes , Spain , 1991.

Hour\Mon	Dec- Jan	February	March	April	May	June	July	August	September	October	November	Σ
01		1		1		5	8	5		4	1	25
02				1	1	7	8	6		4	2	29
03			1	2	3	9	6	6		3	2	32
04	1	2	2	2	4	8	6	5	2	1	3	36
05	2	1	2	4	4	3	7	4	2		2	27
06	3	1	3	3	5	8	9	7	7	2	5	53
07	2			3	6	3	10	8	11	5		46
08	2				2	1	2	4	4	6	2	21
09	3						1	3	1		1	6
10	1						1	1			1	3
11							1	1			2	4
12								1				1
13							1		2		1	4
14				1					1	1		3
15				1					1		1	3
16									1			1
17					1		1	1	1			4
18				1	2	1	3	1			1	9
19						1	1	3				5
20	1						1				2	3
21	3					1	4	3				8
22	2						5	2		2	2	11
23	2					4	7	2			2	15
24	1					2	6	3	1	2	2	16

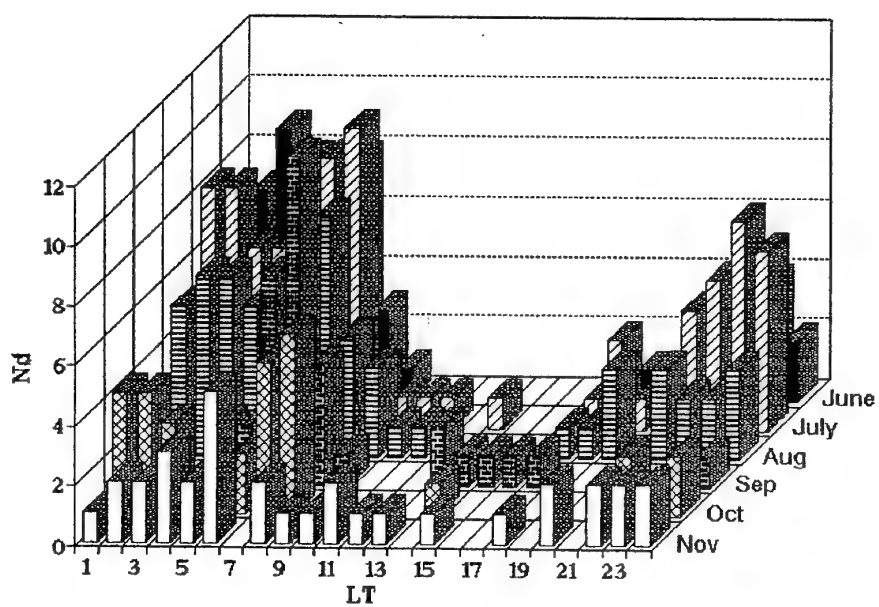
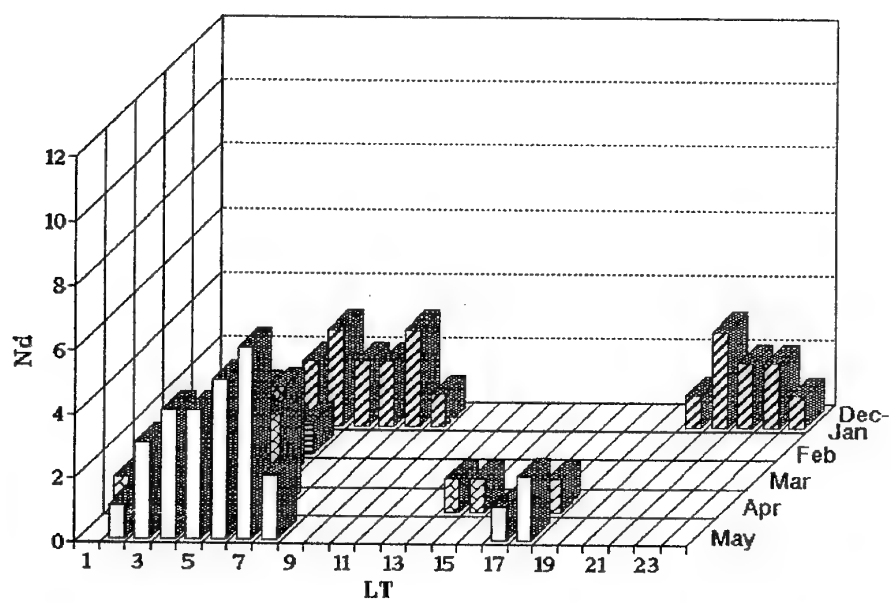


Fig. 5. Number of F traces with strong spread; Roquetes, Spain, 1991.

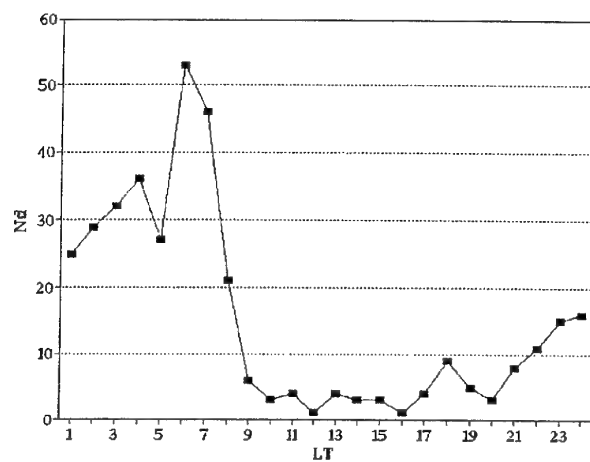


Fig6. Total number Nd of F traces with strong spread (f, ff, fff, fr, r) ; Roquetes, Spain, 1991.

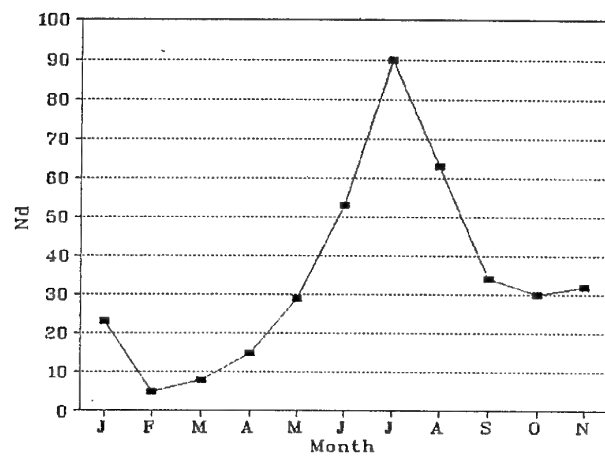


Fig.7. Full number of full disturbed traces; Roquetes, Spain, 1991.

observed very often in the morning hours from July to October with probability from 60 % to 90 %.

One can see that F spread also appears at a day-time (Fig. 3), however with low probability of the order from 5 % to 10 % and always less than 20 %. Nocturnal spread's occurrence reaches 50-60 % in summer.

Seasonal variations of F spread are very well seen in Fig. 4. They are similar to seasonal variations of Sh indexes, Fig. 1.

We discussed above the regularities of F spread, tabulated as strong (index f or r); very strong (ff or ffr); very, very strong (fff) and close to strong with index c. Because this last gradation (c or cr) is not so definite as others, below we give more trustworthy statistics of F spread, which includes only strong F spread with indexes f, ff, fff, r.

Occurrence of strong spread-F is presented in Tables 2, 4 and in Fig. 5-7. Maximum probability of strong spread is equal 13 % in July.

It is seen that the regularities of strong spread to a large extent are similar to the regularities of scattered traces, see p. 4. The main difference appears in the forms of maximums. Maximums of strong-F occurrence Nd are more sharp than the maximums of scattered signals (index Sh). The reason of this is a small number of cases with strong spread.

A number of strong spread Nd correlates rather well with the index Sh of scattered traces what is seen in Tab. 2. Lesser correlation is seen between Nd and mean month sun spot number R as well as it takes place between Sh and R.

6. EFFECT OF TERMINATOR

As it is seen from the obtained data (Fig. 1, 2, 4, 5), spread-F and scattering in F-layer reveals the strong diurnal dependence with large maximum at dawn time and sometime with not so large but noticed maximum at dusk time. To demonstrate this effect of the terminator more clear we calculated the sunrise and sunset time-moments on the

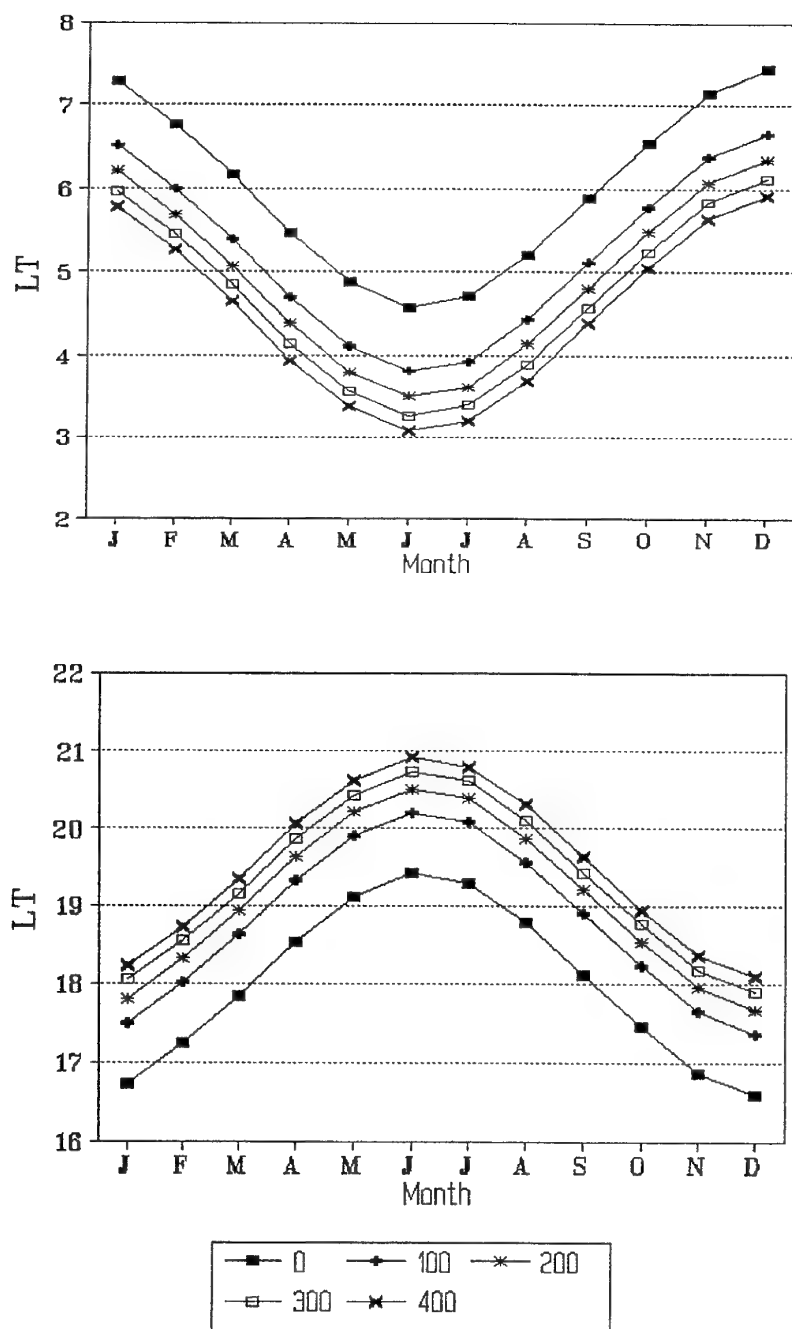


Fig. 8 . The sunrise and sunset time on the Earth and in the ionosphere at the heights 100 , 200 , 300 , 400 km ; station Roquetes , 40.8°N , 0.3°E .

Tab.5. Mean month index S_h of F traces with scattered signals for night (S_N), sunrise (S_{SR}), day (S_D), and sunset (S_{SS}) periods ; station Roquetes , Spain , 1991.

	S_N	S_{SR}	S_D	S_{SS}
January	1.340	1.816	1.593	1.544
February	1.172	1.518	1.273	0.978
March	1.136	1.406	0.995	0.959
April	1.404	1.913	1.242	1.602
May	1.424	2.201	1.258	1.518
June	2.231	2.453	1.344	1.633
July	2.434	2.857	1.877	2.150
August	2.304	2.641	1.803	1.974
September	1.722	2.814	1.992	2.029
October	1.839	2.427	1.768	1.974
November	1.655	2.053	1.762	1.714

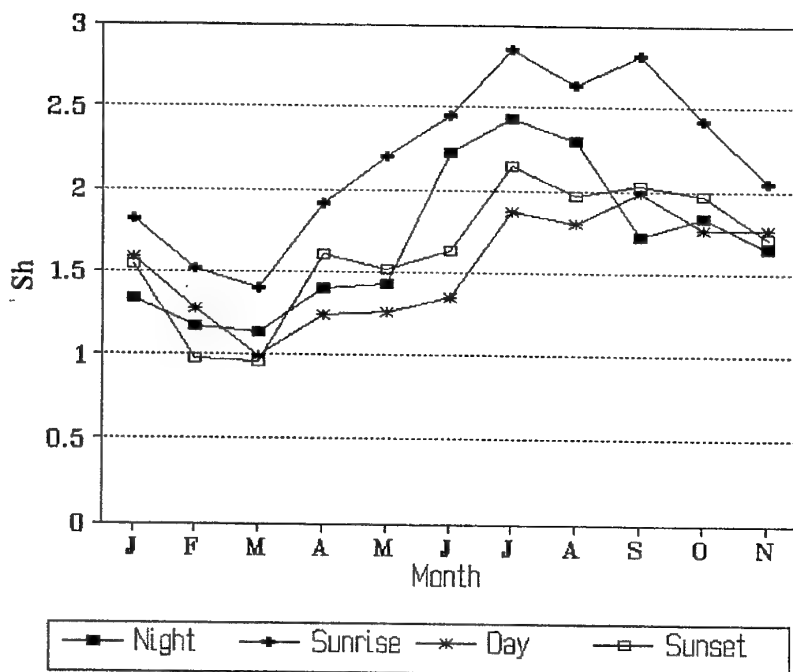


Fig .9. Mean. month index of F traces with scattered signals for night , day and twilight periods ; Roquetes , Spain , 1991.

Tab .6 . Mean month probability P_N in percent of spread echoes c , f , ff , fff , r for night (P_N) , sunrise (P_{SR}) , day (P_D) , and sunset (P_{SS}) periods ; station Roquetes , Spain , 1991.

	P_N	P_{SR}	P_D	P_{SS}
January	16.2	24.2	8.5	11.6
February	6.2	7.1	4.1	4.0
March	5.8	8.1	0.0	0.0
April	9.0	34.4	8.8	15.2
May	13.0	37.0	10.0	10.5
June	36.6	42.6	10.6	16.6
July	44.3	62.9	24.8	35.5
August	38.7	51.9	13.2	8.7
September	14.2	67.6	19.5	5.7
October	21.9	47.7	6.2	6.0
November	22.0	27.5	7.6	3.9

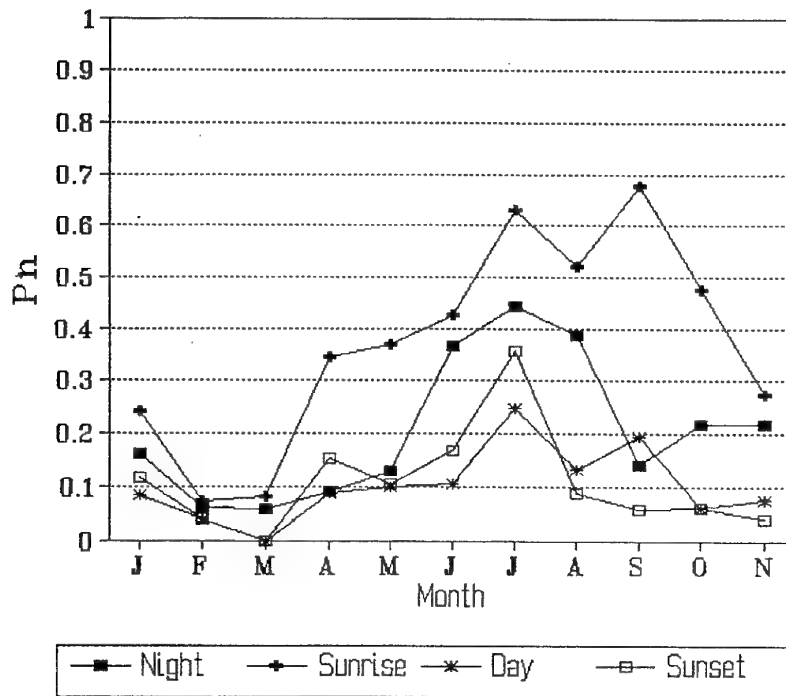


Fig. 10. Mean month probabilities of cases \sqrt{c} , ff, fff, r for night , day and twilight periods ; Roquetes , Spain , 1991.

Table 7. The correlation coefficients r between Ap and spread-F indexes for 3-hour range; Roquetes, Spain, 1991.

LT	r		
	May	August	October
0-3	0.216	-0.605	0.534
3-6	0.049	-0.184	-0.194
6-9	-0.248	-0.235	-0.044
9-12	-0.199	-0.268	-0.285
12-15	0.022	0.455	-0.244
15-18	-0.189	-0.088	-0.356
18-21	-0.256	-0.295	-0.002
21-24	-0.165	-0.297	-0.092

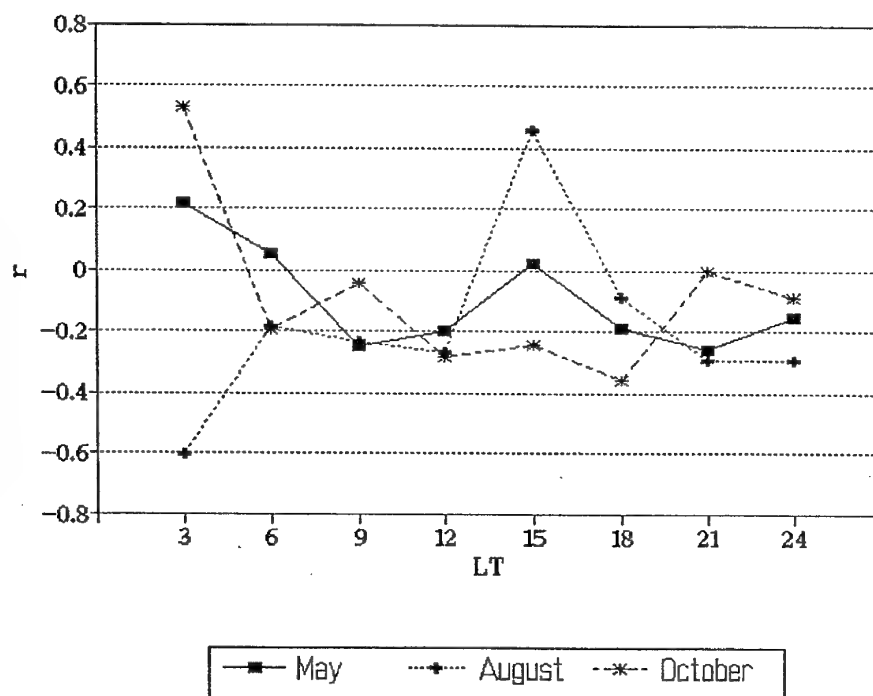


Fig. 11. The correlation coefficients r between Ap and spread-F indexes; Roquetes, Spain, 1991.

Table 8. Month correlation coefficients r between Ap and spread-F indexes; Roquetes, Spain, 1991.

May	August	October
-0.083	-0.163	-0.029

Table 9. The correlation coefficients r between Ap and spread-F indexes; Roquetes, Spain, 1991.

May		August		October	
day	r	day	r	day	r
2 + $\frac{\square}{\Delta}$	-0.405	1 + $\frac{\square}{\Delta}$	-0.004	1 + \square	0.457
3 • $\frac{\square}{\Delta}$	0.496	2 + \square	0.536	4 + $\frac{\square}{\Delta}$	0.143
6	0.546	4 + $\frac{\square}{\Delta}$	0.008	6 • $\frac{\square}{\Delta}$	-0.183
7	0.192	9 \square	-0.551	7 + $\frac{\square}{\Delta}$	-0.023
10 • \square	-0.241	13 \square	0.122	8 + $\frac{\square}{\Delta}$	0.190
11 $\frac{\square}{\Delta}$	-0.560	15 + \square	-0.543	9 • $\frac{\square}{\Delta}$	-0.504
12 $\frac{\square}{\Delta}$	0.464	17 + $\frac{\square}{\Delta}$	-0.272	11 • $\frac{\square}{\Delta}$	-0.288
14 + \square	-0.156	18 $\frac{\square}{\Delta}$	0.096	12 \square	0.363
15 \square	-0.317	19 + \square	-0.566	13 \square	-0.269
17 +	-0.288	23 • $\frac{\square}{\Delta}$	0.288	14 \square	0.060
18	-0.493	24 $\frac{\square}{\Delta}$	0.469	16 \square	0.527
20 $\frac{\square}{\Delta}$	0.108	25 \square	0.486	17 \square	-0.520
22 + $\frac{\square}{\Delta}$	0.270	26 • $\frac{\square}{\Delta}$	-0.050	21 + \square	0.093
23 + \square	-0.341	27 • $\frac{\square}{\Delta}$	-0.480	22 + \square	0.418
27 + $\frac{\square}{\Delta}$	0.487	28 • $\frac{\square}{\Delta}$	0.507	23 •	-0.322
28 + $\frac{\square}{\Delta}$	-0.129	30 + \square	-0.427	24 + \square	-0.173
30 • $\frac{\square}{\Delta}$	-0.298			25 + \square	-0.078
				30 + $\frac{\square}{\Delta}$	-0.648
				31 + $\frac{\square}{\Delta}$	-0.352

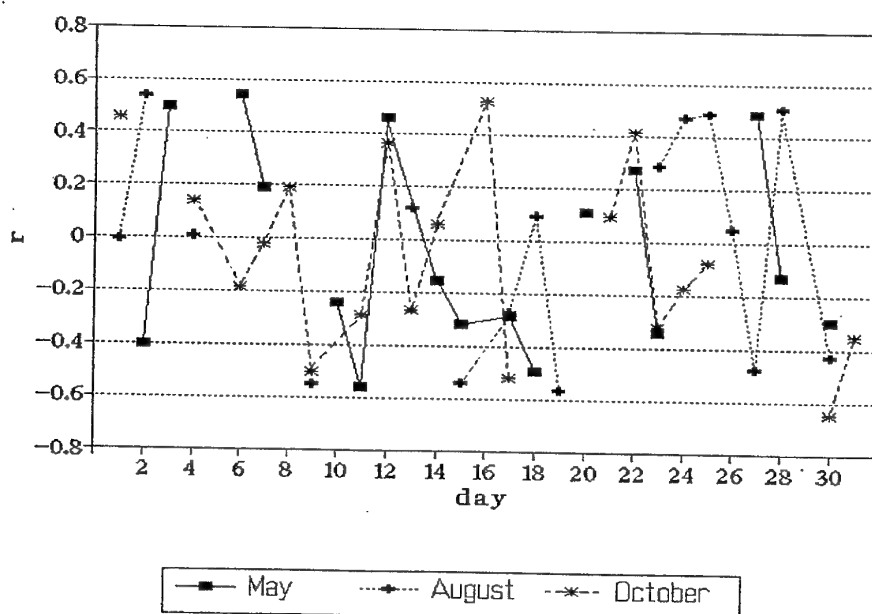


Fig. 12. The correlation coefficients r between Ap and spread-F indexes during three months 1991; Roquetes, Spain, 1991.

Earth and in the ionosphere for Roquetes, Fig. 8. After this we averaged hour indexes of scattering Sh around the sunset and sunrise time and during the day and night hours.

The main indexes Sh for these four periods of time (Sss and Ssr are sunset and sunrise periods, Sd and Sn - day and night periods) are shown in Table 5 and Fig. 9. Sunrise indexes were averaged for 3 hours after sunrise at the height 200 km in the ionosphere, sunset indexes -- for 2 hours before sunset at 200 km. For finding main indexes, intermedium points have been deduced by the spline interpolation of Sh-points with hourly intervals.

It is seen from Fig. 9 and Table 5 that sunrise terminator generates waves and irregularities in the ionosphere and produces F-spread and scattered signals on the ionograms. Main sunrise indexes Ssr are maximum indexes during all months of 1991. Day-time indexes Sd are minimum indexes from April to August. All four indexes are separated from each other in summer. Night indexes Shn are less than sunrise indexes and larger than sunset indexes. Day, night and sunset indexes are mixed in other months and only sunrise indexes always separate from others.

Main probability Pn of the spread echoes with indexes c, f, ff, fff, r for the same night (Pn), sunrise (Psr), day (Pd), and sunset (Pss) periods is presented in Table 6 and in Fig. 10. It has the same regularities as Sh index, Tab. 5 and Fig. 9.

The influence of the terminator on the generation of different size waves and irregularities in the ionosphere has been studied theoretically and experimentally in [40-45].

Our results conform a dramatic impact of terminator on the condition of the ionosphere: the scattering processes are increasing during twilight periods. Sunrise effect of terminator in the most illuminated ionosphere (summer) with many magnetic storms and substorms (also summer period) leads to the spread-F occurrence with a probability in 70-80 %.

The regularities of the index of scattering in the ionosphere and the F-spread appearance are consistent with the results of [37-39].

Table 10. The dates of magnetic storms with $D_{st} \leq -100$ and $-100 > D_{st} \geq -50$ and F spread with indexes c,f,ff,fff, and B.

Month	$D_{st} \leq -100$	$-100 < D_{st} \leq -50$	F spread
January			1-20 data absent 21-23(c) 25(c,f) 26-30(c)
February		1-2	1-2, 4,8,11- 13,17-19, 21,23(c) 20(f) 25(f) 27(c,f,ff)
March	24-27	<u>5</u> 9-10 13 24-28 <u>30</u>	1,7(c) 10(f) 12-13(c,f) 24-26(c,f,ff,fff) 28-29(c,f)
April	29	1-5 27-30	2-4,17-19, 21-22 data absent 5-6,7,8-10(c) 13(c,f,B) 20(fr,B) 23-30(c,f,ff,fff)
May	<u>17</u>	1-2, 14, <u>17</u> 25, 31	1-5(c,f,rf) 8-31(c,f,r,fr,B)
June	5-6 10-11 13-14	1-7, 9-14 18-19, 23-24 30	1-30(c,f,ff,fff,B)

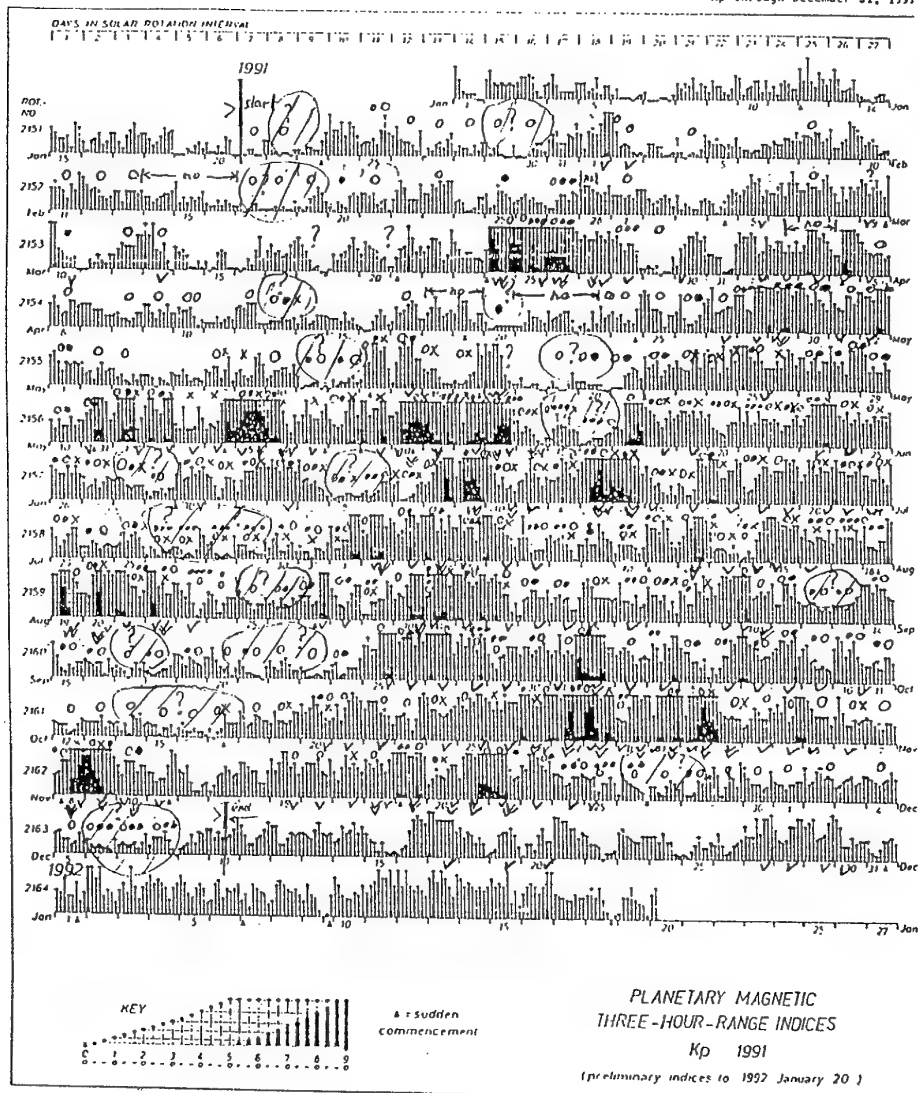
Extention of Table 10

July	9-10 13-15	3 9-11 13-22	1-31(c,f,ff,fff, B)
August	2 4 12 19-21 22 30	2-7 4 12-16 19-23 27-28 30-31	1-31(c,f,ff,fff, B)
September	10	1-6 9-10 25-29	1-30(c,f,ff,fff, B)
October	1-2 27-31	1-4 6-10 20-22 24-31	1-31(c,f,ff, B)
November	1-2 8-10 18-22	1-6 8-11 15-25	1-10(c,f, B) 15-30(c,f,ff,fff,B)
December		17 19-20 27-30	data 1-10 1-8(c,f,ff, B)

PLANETARY 3-HOUR-RANGE INDICES (Kp) BY 27-DAY SOLAR ROTATION INTERVAL

University of Göttingen

Kp through December 31, 1991



no data

○ - 2 (2)
● - 3 (3)
■ - 4 (4)
■ - 5 (5)

X-B, W

$\sqrt{100} |D_{st}| \geq 50, |D_{st}|_{max} \approx 50 \div 90$
 $\sqrt{100} |D_{st}| \geq 100, |D_{st}|_{max} \geq 100$

Fig. 13

7. CONNECTION WITH MAGNETIC ACTIVITY

The connection of F spread with magnetic activity during the year considered was investigated. In this analysis we used K_p , A_p and Dst indexes which characterize the Earth's magnetic activity.

a) Correlations of A_p , K_p and spread-F indexes

Because we used for correlation's calculations 3-hour indexes A_p , we prepared similar 3-hour Sh indexes for F spread. They are provided in Tables 12-14 in APPENDIX for three months -- May, August and October. The days with an absent of the hourly ionograms even for one hour were not considered (zeros in Tab. 12-14). We gave in this performance to the normal traces instead zero Sh indexes, indexes equal to 0.2.

The correlation's coefficients r between 3-hour A_p and Sh spread-F indexes for May, August and October for every 3-hour period are presented in Table 7 and Fig. 11. One can see that r changes from -0.6 to 0.6. The most number of time-intervals has correlation's coefficients close to 0 except intervals from 0 LT to 3 LT and from 12 LT to 15 LT.

Month main correlation's coefficients for May, August and October are given in Tab. 8. It is seen that they are small and negative.

These data show that there are no correlation's connections between F spread and indexes A_p for the period in one month as well, as for 3-hour periods in the most cases.

Correlation for particular days in May, August and October is shown in Tab. 9 and Fig. 12. Symbols plus and points in Tab. 9 in the column with day's numbers point out accordingly or to the days with $K_p > 3$ for all hours (pluses), or to the days with $K_p \approx 3$ for some hours and $K_p > 3$ for the last hours of a day (points). Days with no symbols have K_p less than 3 during all hours of these day-nights (quiet days). Days with not strong spread in Tab. 9 are marked off by squares and with strong spread -- by triangles.

These results clearly demonstrate that the day's correlations during every month have quasi-oscillatory character with the periods of variation from plus to minus equal approximately from 2 to 4 days. This fact explains very small correlation's values for the time-periods in one month (Tab. 8). Data in Tab. 9 point out to very low connections between the value of A_p indexes and spread: correlations do not change while A_p is large. A large number of spread correlates with dawn, night or dusk time but does not correlate usually with the value of planetary magnetic index K_p . Nevertheless, some noticed correlation between numbers of strong spread cases (N_d) and days (n) with strong magnetic disturbances with $\Sigma K_p > 28$ takes place (see Table 2).

b) Dst and spread-F indexes

Dates for every month of 1991 with ring current disturbances are assigned in Tab. 10. The ring current commitments are divided in two categories -- with maximum indexes of ring current $|Dst|_{\max}$ (absolute value) for the commitment reached not less than 100 nT and not less than 50 nT. These categories characterize two types of growth phase of ring current and accordingly magnetic storms --strong and not very strong types. The dates with spread-F and blackouts, and F spread indexes also present in this Table. It is seen that all days with high $|Dst|$ ($|Dst| \geq 100$) agree with the dates with spread-F but not all dates with less $|Dst|$ ($50 \leq |Dst| < 100$) follow by F spread. In the same time, F-spread appears more often than the strong disturbances of ring current, what is seen in Tab. 10.

c) Annual appearance of spread-F in connection with the variations of K_p and Dst indexes

We plotted F-spread indexes', blackouts' (see below p. 9) and high Dst indexes' data on the standard map with planetary 3-hour K_p indexes for 1991. All designations are

shown on this map (Fig. 13). Studying these data together one can assume that a connection of spread-F with magnetic disturbances is not stable and not certain.

The most surprising effect is the appearance of spread during very quiet periods with duration in many days and with $K_p < 3$ and $|Dst| < 20$ or 30 . Such periods were practically observed during every month. They are enclosed in circles and shaded in Fig. 13. It seems that seasons of a year, night-time or terminator produce larger and more determined effects on the spread-F occurrence than magnetic disturbances.

8. ANALYSIS OF MAGNETIC STORM OF 24-26 MARCH 1991

We treat in this paragraph the variations of ionospheric parameters and spread-F during the great magnetic storm of 24-26 March 1991. This magnetic storm started with sudden commencement at 05 UT on the night of March 24. The 3-hour K_p indexes during all period from the start to the end of March 26 were among 5 and 9. They were of the order from 3 to 4 on March 27 and 28, and the 29 March was very quiet day with K_p not more than 1. The Dst index was low till March 24 at 05 UT with main index for March 23 equal to -12 . On March 24 and 25 this index reached $-200 \div -300$. It became a bit less on March 26 -- in range of $-100 \div -150$, and on March 27 -- in range of $-70 \div -100$. The Dst index went down to $-40 \div -75$ on March 27 and 28, and to $-25 \div -40$ on March 29.

The ARTIST's ionospheric parameters foF2 and hmF2, h'F and h'F2, or interpolated their values (marked in Tab.) when the ARTIST gives these parameters with errors, are presented in Tables 15-19 in APPENDIX. The frequencies $fpF2 = 0.834 \text{ foF2}$ and the heights $hpF2 (0.834 \text{ fpF2})$ are given in the same Tables for the cases when ARTIST does not output the profile of electron concentration and the maximum height hmF2 of the F2-layer. We notice that we tried to get maximum heights of F2-layer for these cases using the methods of [45] and [46]. However, the differences between $hpF2 (0.834 \text{ foF2})$, maximum heights, received according the formulas from [45], [46], and

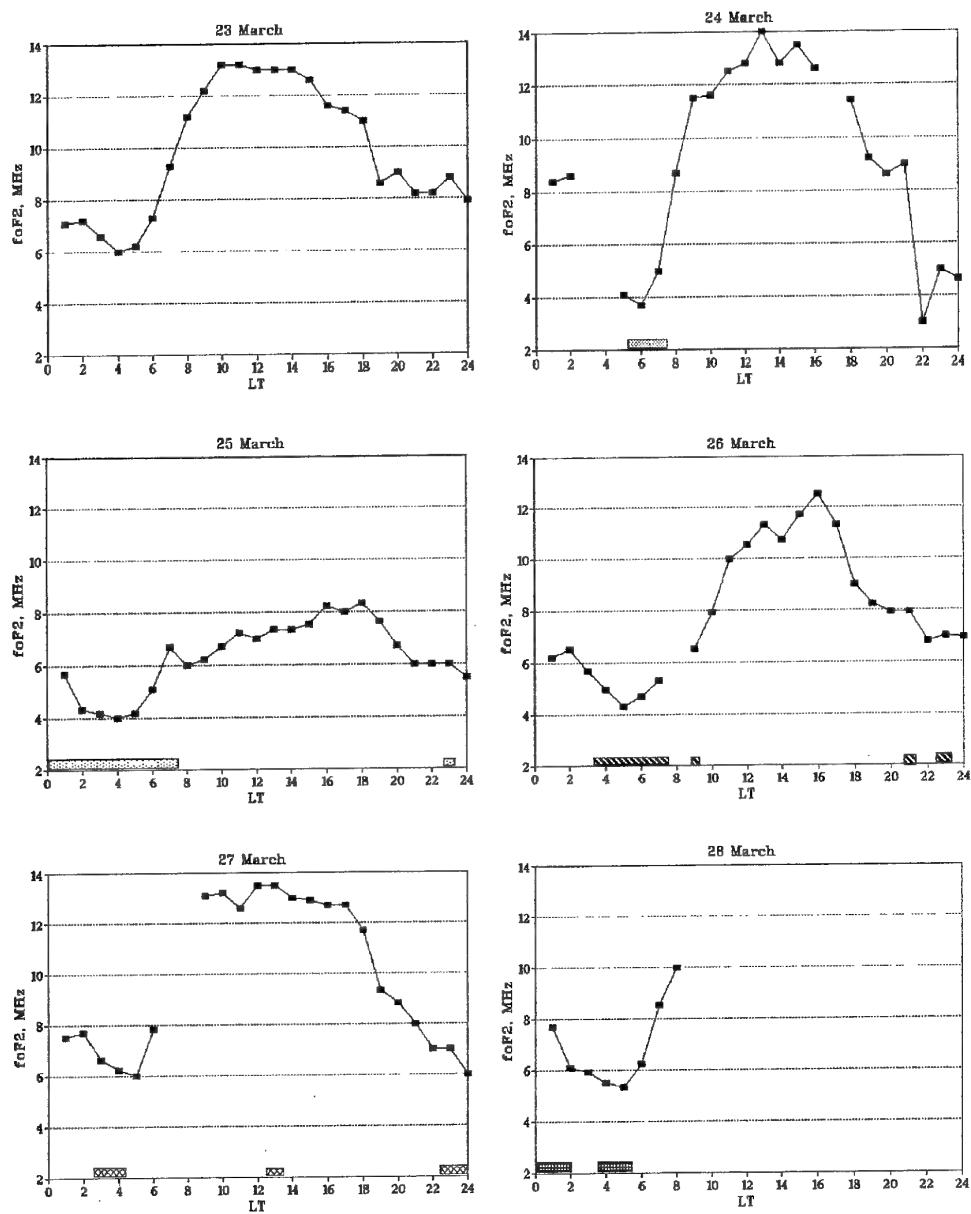


Fig. 14. Critical frequencies foF2 observed at the ionospheric station Roquetes, Spain, 23-28 March 1991. The bars on the X-axis are symbols of the spread-F.

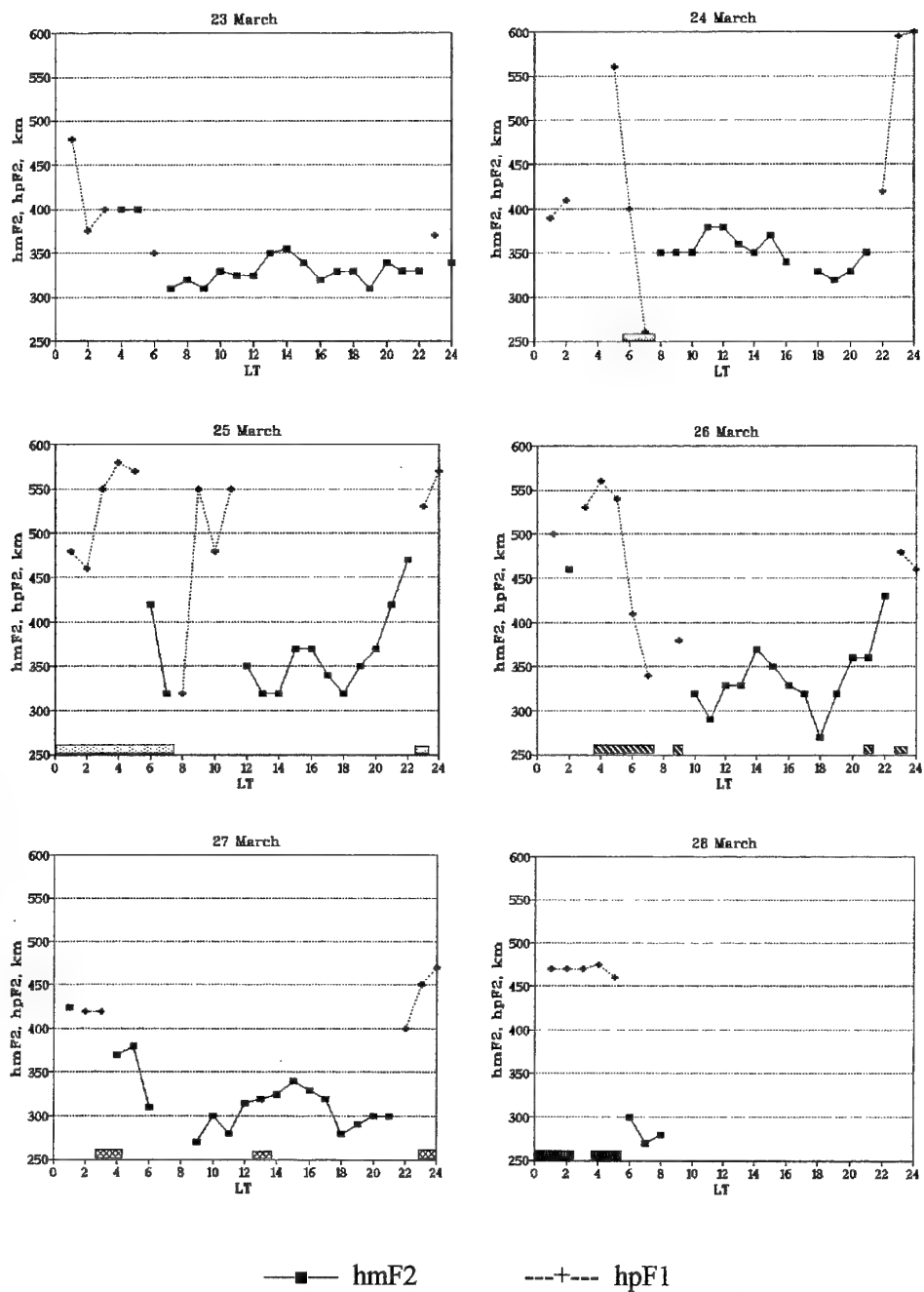


Fig. 15. Maximum heights hmF, hpF2 observed at the ionospheric station Roquetes, Spain, 23 - 28 March 1991. The bars on the X-axis are symbols of the spread-F.

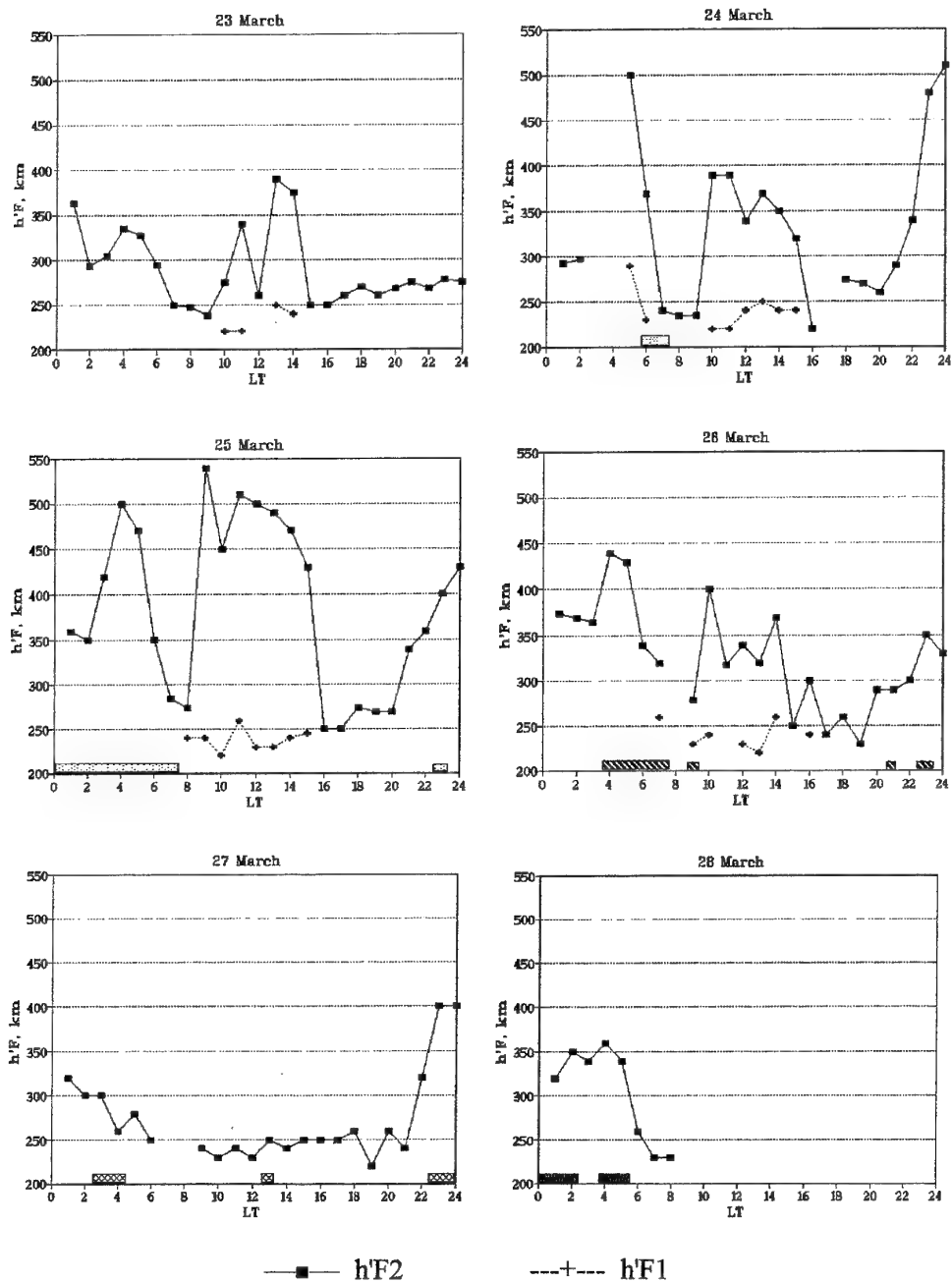


Fig. 16. Minimum heights $h'F$ observed at the ionospheric station Roquetes, Spain, 23 - 28 March 1991. The bars on the X-axis are symbols of the spread-F.

hmF2 (ARTIST) were always very large (until 100 km). That is why, we decided to leave in the Tables 15-20 only the hpF2 values that were recommended in [36] as approximate height for hmF2. The minimum virtual heights h'F and h'F2 also are given in Tab. 15-19.

The variations of all parameters for 23-28 March 1991 are assigned in Fig. 14-16.

The presence of F spread is shown in Tables 15-19 (APPENDIX) by the letter f and in Figures 14-16 by bars.

It is seen from Tab. 15-19 from APPENDIX and Fig. 14-16 that the 23 March was ordinary day. Daily variation of foF2 for this day was close to main variation for all month, Fig. 10, APPENDIX. Some unusual variations of parameters started in the morning of 24 March and continued until 28 March. The decrease of foF2 values on 1-2 MHz and the increase of hmF2 approximately on 70 ÷ 100 km started in the morning hours immediately after sudden commencement. The variations of the parameters were less at day-time but in the evening and night time they were larger than in the morning.

The most disturbed day in ionospheric parameters was the 25 March. The same depletion of foF2 continued during all 25 March. Decrease of foF2 reached 4-5 MHz during day-time. Variations of hmF2, hpF2, h'F1 and h'F2 were very irregular. Maximum heights reached 500 ÷ 550 km. The depletion of critical frequencies was less on March 26. All parameters were close to normal on March 27. Only F-spread with less intensity than in previous days have still presented as before.

Weak spread-F (index c) appeared at once after sudden commencement at 05 LT on March 24 and continued with larger intensity from 00 LT to 07 LT on March 25 (subsequent indexes c, c, f, fff, f, c) and on March 26 from 04 LT to 07 LT with indexes c, ff, ff, c and at 09 LT with index c. Spread-F appeared next day only with index c at 03, 13 and 23 LT. It continued to present on March 28 at night and morning hours with larger intensity (indexes c, c, f, c at 01, 02, 04, 05 LT) when magnetic field and ionospheric parameters were rather close to normal.

This storm was reasonable strong and isolated among very quiet days before and after disturbed days. It produced significant variations in the ionospheric plasma. However, it is the only one event with such tremendous variations in the ionosphere for the whole 1991 observed at the station Roquetes.

9. BLACKOUTS

It follows from Tab. 1-11 (APPENDIX) that many ionograms do not have at all radio signals reflected from the ionosphere (letter B in the Tables) or these signals are very weak (letter W).

A statistics of such cases with lacking traces is presented in Tab. 11 and Fig. 17. It is seen that such events (we will refer to them as "blackouts") take place usually during summer and noon times. In the same time blackouts also appear during other seasons and during morning, evening and night hours but with less probability. There is even the second maximum of blackout occurrences in evening time at 18-20 hours, Tab. 11.

Looking through data in Tab. 1-11 one can see that blackouts, observed in non day-time, appear usually with spread: before, in the middle or after spread-F. It is seen also that blackouts do not appear in rather quiet magnetic period from December to April (see Tab. 2 and Tab. 11). They appear most frequently during the most disturbed period from May to September.

In response to these facts we can conclude that generally blackouts are connected with collision absorption in D and E regions that increases at most illuminated day time-periods in summer solstice, and with the sensitivity limitation of the receiver. Thus, maximum of blackout's occurrences reaches 18 for July at 11 LT, Tab. 11. In the same time they could relate to magnetic disturbances, solar flares and even to terminator. Additional losses of energy because of scattering of radio waves on the irregularities and waves in disturbed ionosphere, may lead to these blackout events. However, these connections require more thorough investigation.

Table 11 Number Na of ionograms with full absorption (-B, -W) ; Roquetes , Spain, 1991 .

Hour/Mon	Dec- Jan	February	March	April	May	June	July	August	September	October	November	Σ
01						2					1	3
02						2					1	3
03						2					1	3
04						3	1			1		5
05							1					1
06						1		2	1	1		5
07						3	1	1				5
08					1	6	6	1				14
09						9	11	2		1	1	24
10					1	12	13	2			2	30
11					1	7	18	5	1			32
12					5	12	6	4	2		2	31
13					6	9	9	2	1			27
14			1		2	9	4	1	1			18
15					1	5	5		1			12
16						2	2	2				6
17					1	1	4		1		1	8
18		1				1	1	2	1	3	2	10
19	1					1	1	2		4	2	10
20					1	2	4	4	1	1		12
21					1		2	3				6
22						1	1	4				6
23					1	1		2		2		6
24					1	1	1	1			1	5

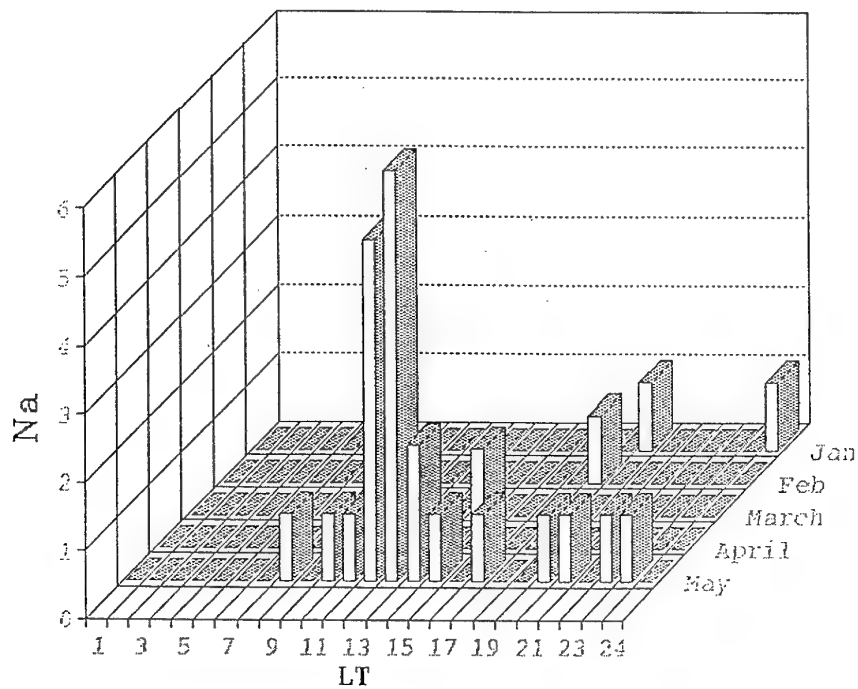
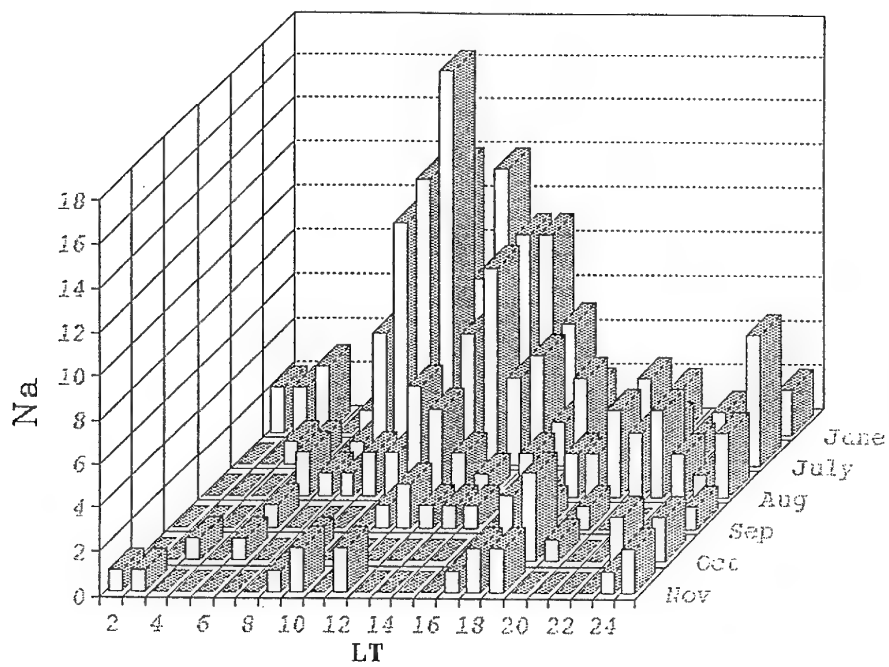


Fig.17. Number of ionograms with full absorbtion ;
Roquetes, Spaine , 1991 .

II. COMPARISON OF THE IRI PARAMETERS WITH MEASURED IONOSPHERIC PARAMETERS

The results of a comparison of the International Reference Ionosphere model (IRI-90) with measured ionospheric parameters at three vertical sounding stations with Digisondes (Dourbes, Belgium; Rome, Italy; and Roquetes, Spain) have been reported in the 1th Interim Report, Sep.-Nov. 1994, submitted at the 30th COSPAR Scientific Assembly, Hamburg, 1994, and represented in the paper

1. H. Soicher, F. Gorman, E. E. Tsedilina and O. V. Weitsman, Comparison of the IRI-90 with measured ionospheric parameters at midlatitudes, Adv. Space Res., 16, No 1, (1)129-(1)132, 1995.

A reader can be acquainted with the results of this work through these sources.

General conclusion of the sources mentioned above is that the IRI-90 represents averaged measured principal parameters of F and E layers at midlatitudes with good accuracy.

III. CONCLUSIONS AND RECOMMENDATIONS

During this work we produced:

1. Updated software created for viewing and printing ionograms, written in ARTIST [11] format.
2. Processing approximately 9000 ionograms with hourly intervals for one year of high solar activity.
3. The method of numerical description of the F trace state on the ionograms and theirs scattered conditions in the ionosphere.

4. Hour, month and year indexes characterizing scattered and disturbed conditions of F traces and F spread occurrences for one year of 1991.
5. Diurnal, seasonal and month probability of spread-F occurrences
6. Probability of strong spread-F occurrence.
7. Effect of terminator on scattering and spread-F.
8. Connection spread-F with magnetic activity.
9. Analysis of ionosphere parameters during great magnetic storm of 24-26 March 1991.
10. Blackout evens for one year.
11. Setting in motion the IRI-90 model..
12. Comparison of IRI-parameters with measured parameters at midlatitudinal vertical sounding stations.

CONCLUSIONS

1. Diurnal maximum of scattering and spread-F occurrence in F-region is observed in sunrise period during all 1991. Probability of F spread reaches 70 % or 90 % in summer's dawns.

2. Daily occurrence of spread-F is less than 20 %, nocturnal occurrence reaches 50 ÷ 60 %.

3. Seasonal maximum of scattering and spread-F is exhibited in summer from June to August.

4. Index of scattering is maximum at dawns during all the year.

5. Maximum probability of strong spread-F in July is equal 13 %.

6. Correlation between F spread indexes and magnetic Ap indexes for the periods in one month is negligible small.

7. Subsequent correlation between F spread and Ap indexes for one day-night period during every month has quasi-oscillatory character and changes approximately from -0.6 to 0.6 with a period from 2 to 4 days.

8. During more quiet period from December to May index of scattering and a number of strong spread-F cases were significantly less than during more disturbed period from June to November.

9. Spread-F is observed both during disturbed periods and during very quiet periods with $K_p < 3$ and $Dst > -30$.

10. Spread-F appeared in morning hours immediately after onset of great magnetic storm of 24-26 March 1991 with big depletion in the ionosphere. It continued to appear in morning and night hours with bigger intensity on 25 and 26 March and two days after the end of the magnetic storm.

11. Most blackout effects take place during summer and day hours.

12. Some blackouts are connected with spread-F occurrences.

13. The IRI-90 model represents averaged principal parameters of F2 and E layers at midlatitudes with rather good accuracy.

RECOMMENDATIONS

This work could be continued in many directions. First of all, it would be interesting to investigate the spread in E-layer (E and Es). An opinion exists that F spread and E spread appear together if E or Es are observed in the time considered. In the same time we do not know the results of such investigations. Our studies have shown that F spread and E spread not always appear in the same time. The subject of E and Es spread in conception with F spread require more detailed examination.

Blackout events should be studied more comprehensively. It would be important to establish the relationship between blackout events and geophysical parameters such as sun radiation, magnetic activity, absorption.

Further, it would be interesting to compare the results, obtained in Spain, with other available data about spread, scintillations and irregularities' observations for the same time-period at European continent and at midlatitudes.

In conclusion it may be said that the problem of appearance of spread and scintillations at midlatitudes is far beyond its understanding. It is necessary to develop the theory of irregularities in midlatitude ionosphere and scattering of the radio waves by acoustic-gravity waves and irregularities in the ionosphere.

Acknowledgments

The authors would like to thank J. Aarons, D. Belitza, G. G. Bowman, K. Rawer and B. Reinish for their kind help with references, discussions and IRI model.

IV. REFERENCES

1. Booker, H. G., P. K. Pasricha, and W. J. Powers, Use of scintillation theory to explain frequency-spread on F-region ionograms, *J. Atmos. Terr. Phys.*, 48, 323-354, 1986.
2. Booker H. G., and Jing-wei Tao, A scintillation theory of the fading of HF waves returned from the F-region: receiver near transmitter, *J Atmos. Terr. Phys.*, 49, 915-938, 1987.
3. Bowman, G. G., Some aspects of midlatitude daytime ionospheric disturbances, *J. Atmos. Terr. Phys.*, 54, 1513-1521, 1992.
4. Bouman, G. G., Large-scale ionospheric structures associated with mid-latitude spread F, *J. of Geoph. Res.*, 96, No A6, 5955-5958, 1988.
5. Fejer, B. G., and M. C. Kelly, Ionospheric irregularities, *Review of Geophysics and Space Sci.*, 18, No 2, 401-454, May 1980.
6. Aarons, J., G. Gurgiolo, and A. S. Rodger, The effects of magnetic storm phases on F layer irregularities from auroral to equatorial latitudes, *Proc. The Ionospheric Effects Symposium, Naval Res. Lab., Washington, DC 20375*, 527-537, 1987.
7. Briggs, B. H., Observations of radio star scintillations and spread-F echoes over a solar cycle, *J. Atmos. Terr. Phys.*, 26, 1-23, 1964.
8. Busu, S., S. Busu, S. Ganguly, and J. A. Klobuchar, Simultaneous incoherent scatter and scintillations/ total electron content observations in the midlatitude ionosphere, paper, presented at the National Radio Science Meeting, Union Radio Sci., Boulder, Colo., 1979.
9. Rodger, A. S., and J. Aarons, Studies of ionospheric F-region irregularities from geomagnetic midlatitude conjugate regions, *Radio Sci.*, 30, 63-72, 1988.
10. Pryse, S. E., L. Kersley, and C. D. Russell, Scintillation near the F layer trough over northern Europe, *Radio Science*, 26, No 4, 1105-1114, 1991.

11. Rainish, B. W., New techniques in ground-based ionospheric sounding and studies, *Radio Science*, 21, 331-341, 1986.
12. Korinevskaya, N. A., Spread and oblique reflections from the F-reflections, *Geom. and Aeron.*, 8, No 2, 271-274, 1968.
13. Bowman, G. G., Small-scale stratifications associated with daytime travelling ionospheric disturbances in midlatitude regions, *Annale Geophysicae*, 6,(2), 187-194, 1988.
14. MacDougall, J. W., Sources of high-mid-latitude scintillations in the American zone at 53° N, *Radio science*, 25, No 5, 813-823, 1990.
15. Bowman, G. G., A review of some recent work on midlatitude spread-F occurrence as detected by ionosondes, *J. Geomag. Geoelectr.*, 42, 109-138, 1990.
16. Advise, R. M., Jr., The occurrence of spread F on HF propagation, Report 28, US. Dep. of Commun. and Telecommun. Res. and Eng., 1972.
17. Aarons, J., Global morphology of ionospheric scintillations, *Proc. IEEE*, 70(4), 360-378, 1982.
18. Kumagai, H., Mid-latitude ionospheric scintillations and geomagnetic activity, *J. Geomag. Geoelect.*, 38, 267-274, 1986.
19. Huang, Yinn-Nien, and Chung-Yauw Yeh, On the occurrence of spread-F and the geomagnetic activity over Taipei, Taiwan, *J. Atmos. Terr. Phys.*, 32, 1765-1772, 1970.
20. Bowman, G. G., The influence of the upper-atmosphere neutral particle density on the occurrence of equatorial spread-F, *Ann. Geophysics.*, 11, 624-633, 1993.
21. Saksena, R. C., Occurrence statistics for spread-F over Indian sub continent, *Adv. Space Res.*, 18, 1995 (in press).
22. Booker, H. G., The role of acoustic gravity waves in the generation of spread-F and ionospheric scintillation, *J. Atmos. Terr. Phys.*, 41, 501-515, 1979.
23. Kelly, M. C., M. F. Larsen, C. La Hoz, and J. P. McClure, Gravity wave initiation of equatorial spread-F: A case study, *J. Geophys. Res.*, 86., 9087-90100, 1981.

24. Sinno K., and M. Kan, Midlatitude ionospheric scintillations of VFH radio signals associated with peculiar fluctuations on Faraday rotation, *J Atmos. Terr. Phys.*, 40, 503-506, 1978.
25. Lei, Y. H., X. Q. Pi, D. Y. Ye, and B. X. Liang, Nocturnal ionospheric scintillations, spread-F and TEC wave-like perturbation at Wuchang, *Proc. Int. Symp. Space Phys.*, Beijing, Nov. 5-054-5-057, 1986.
26. Goncharova, E. E., V. M. Shashunkina, L. A. Judovich, Prediction of the F2 parameters during substorms, *Geom. Aeron.*, 25, 308-310, 1985 (in Russian).
27. Buonsato, M. J., J. C. Foster, and D. P. Sipler, Observations from Millstone Hill during the geomagnetic disturbances of March and April 1990, *J. Geoph. Res.*, 97, No A2, 1225-1243, 1992.
28. Aarons, J., and A. S. Rodger, Sub-auroral F-layer irregularities and the ring current, *Ann. Geophys.*, 7, 169-176, 1989.
29. Aarons, J., The role of ring current in the generation or inhibition of equatorial F layer irregularities during magnetic storms, *Radio Sci.*, 26, 1131-1199, 1991.
30. Wright, I. W., I. P. WcClue, and W. B. Hanson, Comparisons of ionograms and OGO 6 satellite observations of small-scale F region inhomogeneities, *J. Geoph. Res.*, 82, 548-554, 1977.
31. Dyson, P. L., Comparison of scintillation, spread-F and electrostatic probe observations of electron density irregularities, *J. Atmos. Terr. Phys.*, 33, 1185-1190, 1971.
32. Gershman, B. N., Dynamics of ionospheric plasma, Moscow, Nauka, 1974, 256p., (in Russian).
33. Bowman, G. G., Delayed midlatitude spread-F occurrence following enhanced geomagnetic activity, *Indian Journal of Radio & Space Physics*, 21, 80-88, 1992.
34. Galkin, I. A., R. R. Gamache, J. L. Scali, and Jane Tang, MMM, ARTIST and Raw Dump Formats, Technical report 9503/IG, Univ. of Mass., Lowell Centere for Atmos. Res., 1995.

35. Gamache, R. R., T. Bullet, Z. Zhang, B. W. Reinish, and W. T. Kersey, ADEP Database Record Structure, Univ. of Mass., Lowell Center for Atmos. Res. 1992.
36. Piggott, W. R., and K. Rawer, Editors, U.R.S.I., Handbook of ionogram interpretation and reduction, World Data Center A for Solar-Terrestrial Physics Report UAG-23, and 23A, Boulder CO (1978). Rukovodstvo URSI po interpretazii i obrabotke ionogram, Pub. "Nauka", M., 1978, p.372 (in Russian)..
37. Tsedilina, E. E., Influence of terminator and sunspot activity on short wave field strength over long-distance paths, Geomagn. Aeron., 30, 337-340, 1990 (in Russian).
38. Tsedilina, E. E., HF radio wave field strength on long mid-latitude paths, Radio Sci., 27, 981-990, 1992.
39. Tsedilina, E. E., HF radio field strength and total propagation invariants, 29, 127-134, 1994.
40. Cole, K. D., Energetics of and a source of energy for equatorial spread-F events, J. Atmos. Terr. Phys., 36, 1099-1102, 1974.
41. Beer, T., Supersonic generation of atmospheric waves, Nature, 242, 34-35, 1973.
42. Somsicov, V. M., The solar terminator and atmospheric dynamics, Nauka Press, Alma-Ata, 1983, 192 p., (in Russian).
43. Antonova, V. P., S. S. Gusseinov, V. I. Drobxhev et al., Isv. Akad. Nauk U.S.S.R., ser. fiz. atm. okean, 24, 134-142, (in Russian).
44. Mishin, E. V., A. E. Episheva, L. M. Ishkova et al., Disturbances of F-region electron density following solar terminator during the WITS period of 16-20 March 1988, J. of Atmos. Terr. Phys., 53, 643-648, 1991.
45. Alimov O., N. P. Marchenko, L. N. Rubzov, E. E. Tsedilina, I. A. Tushenzova, Effect of the dusk and down terminator on the dynamics of backscatter oblique-incidence sounding signals in angular scanning of the ionosphere at 20 MHz in Dushanbe, Geom. and Aeron., 31, 335-339, 1991.
46. Gulyaeva, T., L., Progress in ionospheric informatics based on electron density profile analysis of ionograms, Adv. Space Res., 10, 123-126, 1990.

47. Shimazaki, T., Worldwide daily variability in the height of the maximum electron density of the ionospheric F2-layer, J. Radio Res. Labs. (Japan) 2, 85-97, 1955.

V. APPENDIX

Table 2. March 1991 Scott

d	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
2	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
3	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
4	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
5	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
6	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
7	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
8	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
9	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
10	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
11	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
12	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
13	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
14	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
15	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
16	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
17	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
18	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
19	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
20	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
21	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
22	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
23	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
24	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
25	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
26	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
27	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
28	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
29	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
30	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
31	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
Sr	40	32	34	47	50	418	30	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
N	30	30	29	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
P	1.73	1.07	1.17	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	

259
24-1/2
N.D. = 7

Table 3 April 1997

d	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
2	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
3	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
4	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
5	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
6	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
7	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
8	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
9	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
10	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
11	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
12	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
13	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
14	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
15	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
16	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
17	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
18	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
19	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
20	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
21	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
22	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
23	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
24	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
25	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
26	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
27	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
28	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
29	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
30	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
31	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
Σ	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
N	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
P	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19

$$P_5 = 0.053 \pm 0.003$$

$$P_6 = 0.19 \pm 0.16$$

$$P_7 = 0.34 \pm 0.16$$

$$P_8 = 0.19 \pm 0.16$$

$$P_9 = 0.19 \pm 0.16$$

$$P_{10} = 0.19 \pm 0.16$$

$$P_{11} = 0.19 \pm 0.16$$

$$P_{12} = 0.19 \pm 0.16$$

$$P_{13} = 0.19 \pm 0.16$$

$$P_{14} = 0.19 \pm 0.16$$

$$P_{15} = 0.19 \pm 0.16$$

$$P_{16} = 0.19 \pm 0.16$$

$$P_{17} = 0.19 \pm 0.16$$

$$P_{18} = 0.19 \pm 0.16$$

$$P_{19} = 0.19 \pm 0.16$$

$$P_{20} = 0.19 \pm 0.16$$

$$P_{21} = 0.19 \pm 0.16$$

$$P_{22} = 0.19 \pm 0.16$$

$$P_{23} = 0.19 \pm 0.16$$

$$P_{24} = 0.19 \pm 0.16$$

$$P_{25} = 0.19 \pm 0.16$$

$$P_{26} = 0.19 \pm 0.16$$

$$P_{27} = 0.19 \pm 0.16$$

$$P_{28} = 0.19 \pm 0.16$$

$$P_{29} = 0.19 \pm 0.16$$

$$P_{30} = 0.19 \pm 0.16$$

$$P_{31} = 0.19 \pm 0.16$$

Tabbs, June 1991

[illegible]

Table August 24

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
2	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
3	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
4	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24			
5	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				
6	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24					
7	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24						
8	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24							
9	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24								
10	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24									
11	11	12	13	14	15	16	17	18	19	20	21	22	23	24										
12	12	13	14	15	16	17	18	19	20	21	22	23	24											
13	13	14	15	16	17	18	19	20	21	22	23	24												
14	14	15	16	17	18	19	20	21	22	23	24													
15	15	16	17	18	19	20	21	22	23	24														
16	16	17	18	19	20	21	22	23	24															
17	17	18	19	20	21	22	23	24																
18	18	19	20	21	22	23	24																	
19	19	20	21	22	23	24																		
20	20	21	22	23	24																			
21	21	22	23	24																				
22	22	23	24																					
23	23	24																						
24	24																							
25																								
26																								
27																								
28																								
29																								
30																								
31																								
Σ																								
N																								
P _n																								

Pa = 54
24 = 2.13

5

Table 8. Scatter Plot 9.1

[illegible]

Table November 91

d	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
2	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
3	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
4	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
5	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
6	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
7	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
8	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
9	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
10	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
11	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
12	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
13	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
14	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
15	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
16	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
17	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
18	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
19	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
20	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
21	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
22	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
23	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
24	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
25	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
26	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
27	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
28	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
29	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
30	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
31	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
Σ	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
N	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
P	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33

$P_0 = 1/18 = 771$
 $N_0 = 582$

14.1

Tab. 11. January 1907 Southern

h	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
21	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
22	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
23	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
24	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
25	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
26	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
27	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
28	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
29	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
30	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
31	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
ΣK	6+4	8+2	9+3	10+4	11+5	12+6	13+7	14+8	15+9	16+10	17+11	18+12	19+13	20+14	21+15	22+16	23+17	24+18	25+19	26+20	27+21	28+22	29+23	30+24
ΣK	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57
N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Ph	1.22	0.9	1.3	0.9	1.3	0.9	1.3	0.9	1.3	0.9	1.3	0.9	1.3	0.9	1.3	0.9	1.3	0.9	1.3	0.9	1.3	0.9	1.3	0.9
f	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
2	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
3	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
4	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
5	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
6	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
7	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
8	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
9	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
10	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc
ΣK	6+8	8+10	10+12	12+14	14+16	16+18	18+20	20+22	22+24	24+26	26+28	28+30	30+32	32+34	34+36	36+38	38+40	40+42	42+44	44+46	46+48	48+50	50+52	52+54
ΣK	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
N	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Ph	1.4	1.6	1.7	1.5	1.4	1.6	1.7	1.5	1.4	1.6	1.7	1.5	1.4	1.6	1.7	1.5	1.4	1.6	1.7	1.5	1.4	1.6	1.7	1.5

P_1 1.31 1.25 1.5 1.2 1.9 1.5 1.75 1.5 2.35 1.3 1.3 1.48 1.52 1.5 1.56 2.11 1.35 9.84 1.01 1.02 1.81 1.95 1.25 1.33 1.53
 (2.78)

Table 12. Spread F 3-hour range indexes for October 1991; Roquetes, Spain.

day/LT	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24
1	5	5	7	4	7	6	6	7
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	6	6	10	4	3	6	7	5
5	0	0	0	0	0	0	0	0
6	3.2	7	11	8	5	7	8	5
7	8	5	11	7	6	6	6	9
8	2.4	4	10	6	6	7	6	6
9	4.2	4.2	11	5	6	6	7	6.2
10	0	0	0	0	0	0	0	0
11	7	9	10	4	4	6	5	5
12	4	4.2	7	6	3	6	6	6
13	4	8	8	6	5	6	6	6
14	3.2	6	9	4.2	4.2	6	7	7
15	0	0	0	0	0	0	0	0
16	6	8	8	5	5	6	6	5
17	4.2	4.2	6	5	3	5	6	5.2
18	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0
21	2.2	5	7	6	5	6	5	3.2
22	3.2	2.2	7	6	5	4	5	2.2
23	6	3.2	6	5	5	6	6	3.4
24	6	5	5.2	6	6	6	6	4
25	13	12	4	2.4	4	5	6	9
26	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0
30	8.2	5	7	3	3	4	5	3.2
31	8.2	5	7	3	3	4	5	3.2

Table 13. Spread F 3-hour range indexes for August 1991; Roquetes, Spain.

Day/LT	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24
1	6	10	8	4	6	6	6	9
2	5.2	2.4	7	6	5	4	5	4
3	0	0	0	0	0	0	0	0
4	4	6	8.2	3.2	6.2	3.4	3.2	7
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	9	4.2	6	4	3	6	6	7
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
13	5	3	7	3.4	2.2	5	6	6
14	0	0	0	0	0	0	0	0
15	3.4	5	8	6	5	7	6	6
16	0	0	0	0	0	0	0	0
17	12	10	7	6	4	4	5	8
18	7	11	6	3	4	3.2	6	7
19	8	7	6	3	7	5	6	7
20	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0
23	7	12	6	6	5	6	6	7
24	11	12	12	7	2.2	5	6	6
25	7	7	9	7	5	6	6	7
26	8	7	9	4.2	3	5	8	7
27	7	9	11	6	6	3.2	6	3.2
28	10	7	6	5	6	5	6	8
29	0	0	0	0	0	0	0	0
30	8	6	6	4	6	6	4.2	4.2
31	0	0	0	0	0	0	0	0

Table 14. Spread F 3-hour range indexes for May 1991; Roquetes, Spain.

day/LT	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24
1	0	0	0	0	0	0	0	0
2	6	5	10	1.4	3.2	2.2	4	6
3	5	8	9	4.2	2.2	3	5	4.2
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	6	5	4	3.2	3.2	2.2	2.2	3.2
7	4	5	4	2.2	4	4	3.2	3
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
10	2.4	6.2	7	1.4	0.6	7	8	3
11	5	8	11	7	4	4	8	5
12	5	8	7	6	5	4	9	6
13	0	0	0	0	0	0	0	0
14	4.2	9	7	6	1.4	3.2	3.2	4.2
15	1.4	1.4	6	4	0.6	4	8	6
16	0	0	0	0	0	0	0	0
17	3.2	3	2.2	0.6	1.4	2.2	3	5
18	0.6	3	4	4.2	1.4	3	4	4
19	0	0	0	0	0	0	0	0
20	4	5	9	4.2	2.2	3	5	3
21	0	0	0	0	0	0	0	0
22	7	10	12	3.2	2.4	5	5	2.2
23	6	4	8	3	3.2	4.2	4.2	2.2
24	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0
27	5	7.2	5	5	4	1.4	5	2.2
28	7	12	9	3	2.2	2.2	4	4
29	0	0	0	0	0	0	0	0
30	7	11	3.2	5	1.4	4	4	4
31	0	0	0	0	0	0	0	0

Table 15. Ionospheric data; Roquetes, Spain, 23 March 1991.

LT	foF2	hmF2	hpF2	fpF2	h'F	h'F2
1	7.1		480	5.9	363	
2	7.2		375	6.0	293	
3	6.6		400	5.5	305	
4	6.0	400			335	
5	6.2	400			328	
6	7.3 ^		350	5.42	295	
7	9.3 ^	310			250	
8	11.2	320			248	
9	12.2	310			238	
10	13.2	330			275	220 F1
11	13.2	325			340	220 F1
12	13.0	325			260	
13	13.0	350			390	250 F1
14	13.0	355			375	240 F1
15	12.6	340			250	
16	11.6	320			250	
17	11.4	330			260	
18	11.0 ^	330			270	
19	8.6 ^	310			260	
20	9.0 ^	340			268	
21	8.0 ^	330			275	
22	8.2 ^	330			268	
23	8.8		370	7.3	278	
24	7.9	340			275	

^ - interpolated values because of the ARTIST program mistakes .

Table 16. Ionospheric data; Roquetes, Spain, 24 March 1991.

LT	foF2	hmF2	hpF2	fpF2	h'F	h'F2
1	8.4		390	7.0	293	
2	8.6		410	7.2	298	
3						
4						
5	4.1		560	3.4	470	390 F1
6	3.7 ^ f		400	3.1	370	230 F1
7	5.0 ^ f		260	4.2	240	
8	8.7	350			235	
9	11.5	350			235	
10	11.6	350			390	220 F1
11	12.5	380			390	230 F1
12	12.8	380			340	240 F1
13	14.0	360			370	250 F1
14	12.8 ^	350			350	240 F1
15	13.5 ^	370			320	240 F1
16	12.6 ^	340			220	
17						
18	11.4 ^	330			275	
19	9.2 ^	320			270	
20	8.6 ^	330			260	
21	9.0 ^	350			290	
22	3.0 ^		420	2.5	340	
23	5.0 ^		595	4.2	480	
24	4.6 ^ f		600	3.8	510	

f - spread; ^ - interpolated values because of the ARTIST program mistakes .

Table 17. Ionospheric data; Roquetes, Spain, 25 March 1991.

LT	foF2	hmF2	hpF2	fpF2	h'F	h'F2
1	5.7 ^ f		480	4.75	360	
2	4.3 ^ f		460	3.6	350	
3	4.2 ^ f		550	3.56	420	
4	4.0 ^ f		580	3.3	500	
5	4.2 ^ f		570	3.56	470	
6	5.1 f	400			350	
7	6.7 f	320			285	
8	6.0		320	5.0	275	240 F1
9	6.2 ^		550	5.17	540	240 F1
10	6.7 ^		480	5.6	450	220 F1
11	7.2 ^		550	6.0	510	260 F1
12	7.0 ^ w	350			500	230 F1
13	7.3 w	320			490	230 F1
14	7.3 ^	330			470	240 F1
15	7.5 ^	370			430	245 F1
16	8.2 ^	370			250	
17	8.0 ^	340			250	
18	8.3 ^	320			275	
19	7.6 ^	350			270	
20	6.7 ^	370			270	
21	6.0	420			340	
22	6.0 ^	470			360	
23	6.0 ^ f		530	5.0	400	
24	5.5 ^		570	4.6	430	

f- spread, w - very weak signal, ^ - interpolated values because of the ARTIST program mistakes.

Table 18. Ionospheric data; Roquetes, Spain, 26 March 1991.

LT	foF2	hmF2	hpF2	fpF2	h'F	h'F2
1	6.2		500	5.2	375	
2	6.5	460			370	
3	5.7		530	5.0	365	
4	5.0 ^ f		560	4.2	440	
5	4.3 ^ f		540	3.6	430	
6	4.7 ^ f	330	410	3.9	340	
7	5.3 f		340	4.4	320	260 F1
8						
9	6.5 f		380	5.3	280	230 F1
10	7.9 ^	320	410	6.6	400	240 F1
11	10.0 E	290			318	
12	10.5	330			340	230 F1
13	11.3	330			320	220 F1
14	10.7	370			370	260 F1
15	11.7	350			250	
16	12.5	330			300	240 F1
17	11.3 ^	320			240	
18	9.0 ^	270			260	
19	8.2 ^	320			230	
20	7.9 ^	360			290	
21	7.9 ^ f	360			290	
22	6.8	430			300	
23	7.0 ^ f		480	5.8	350	
24	6.9		460	5.8	330	

f - spread, ^ - interpolated values because of the ARTIST program mistakes.

Table 19. Ionospheric data; Roquetes, Spain, 27 March 1991.

LT	foF2	hmF2	hpF2	fpF2	h'F
1	7.5	425			320
2	7.7		420	6.4	300
3	6.6 f		420	5.5	300
4	6.2 ^ f	370			260
5	6.0 ^	380			280
6	7.8	310			250
7					
8					
9	13.1 ^				240
10	13.2	300			230
11	12.6	280			240
12	13.5	315			230
13	13.5 f	320			250
14	13.0 ^	325			240
15	12.9 ^	340			250
16	12.7	330			250
17	12.7 ^	320			250
18	11.7 ^	280			260
19	9.3 ^	290			220
20	8.8 ^	300			260
21	8.0 ^	300			240 E
22	7.0 ^		400	5.8	320 E
23	7.0 ^ f		450	5.8	400 E
24	6.0 ^ f E		470	5.0	400 E

Table 20. Ionospheric data; Roquetes, Spain, 28 March 1991.

LT	foF2	hmF2	hpF2	fpF2	h'F
1	7.7 f		470	6.4	320
2	6.1 f		470	5.1	350
3	5.9		470	4.9	340
4	5.5 f		475	4.6	360
5	5.3 f ^		460	4.4	340
6	6.2	300			260
7	8.5 ^	270			230
8	10.0	280			230

f - spread, E - blanketing by Es, ^ - interpolated values because of the ARTIST program mistakes.

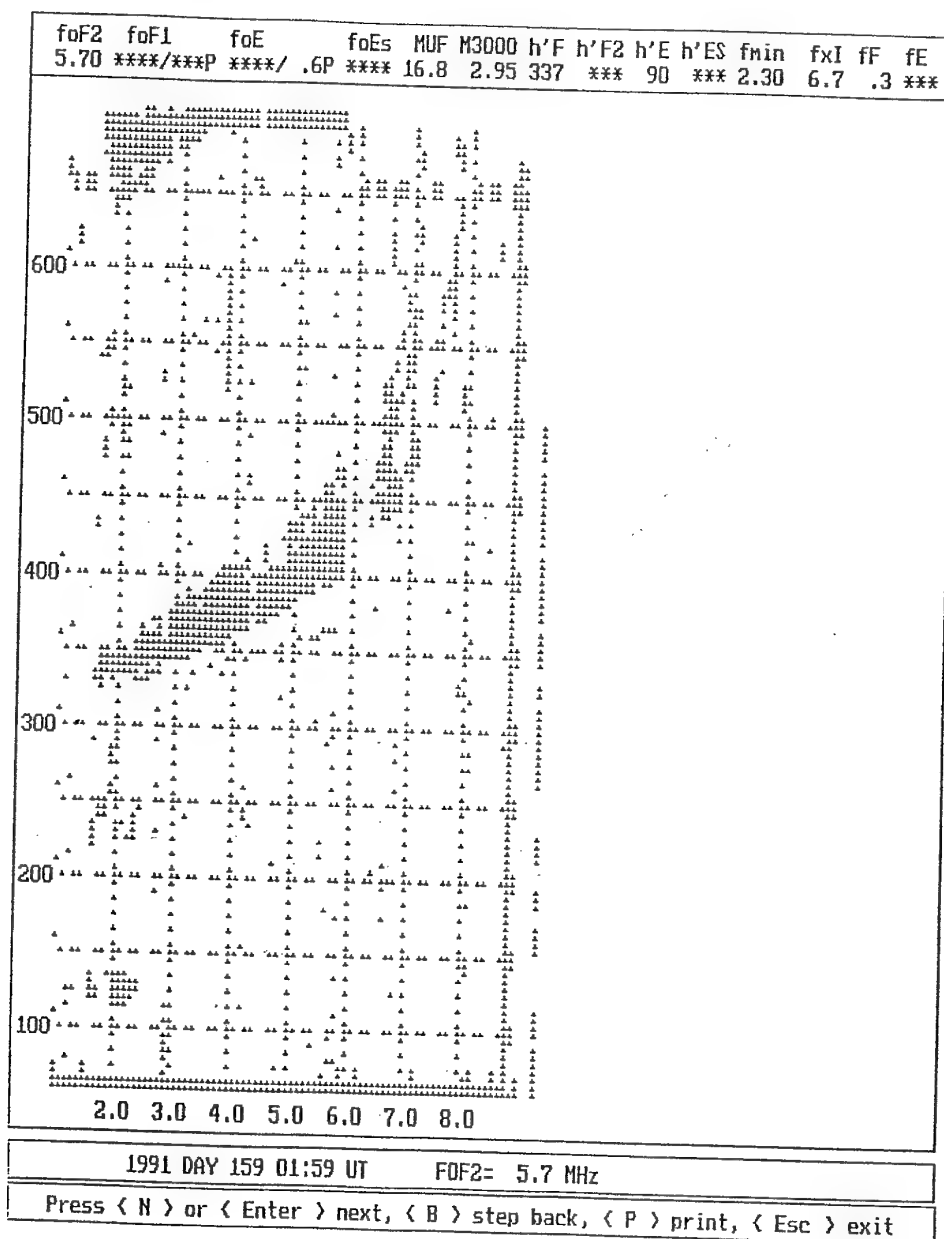


Fig. 1. 8 June 1991, index ffA

Figures 1-9. Examples of ionograms with F spread.

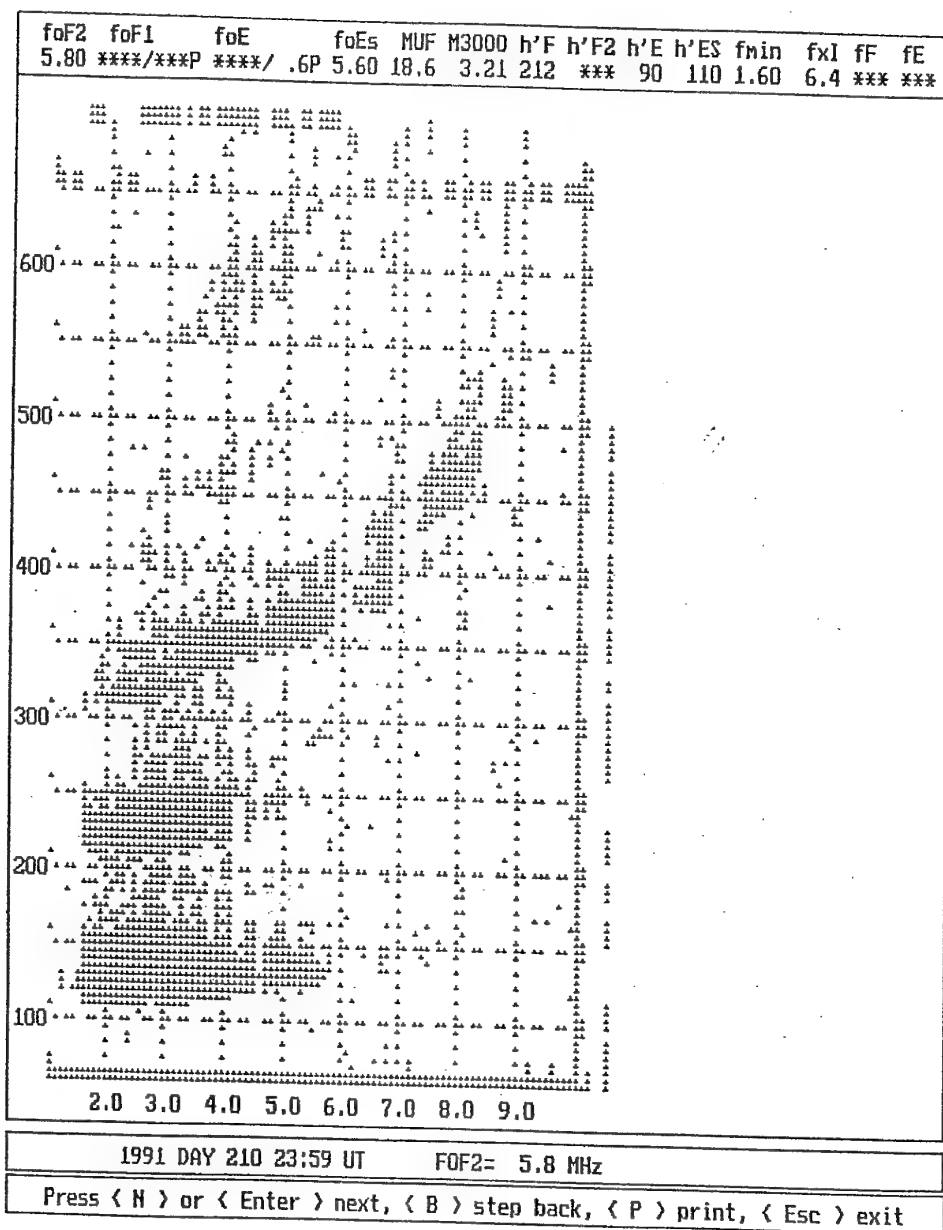


Fig. 2. 29 July 1991, index fffA

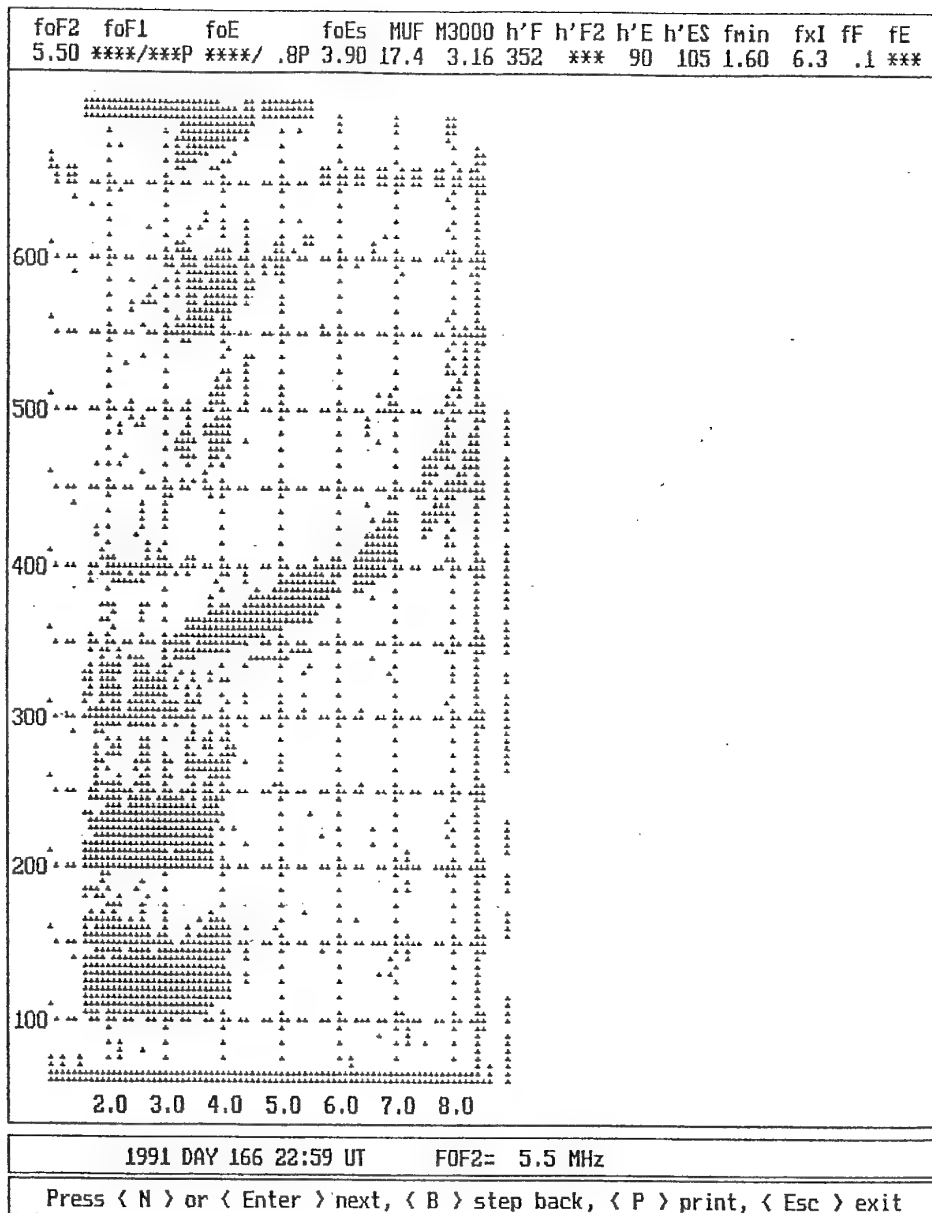


Fig. 3. 15 June 1991, index fA

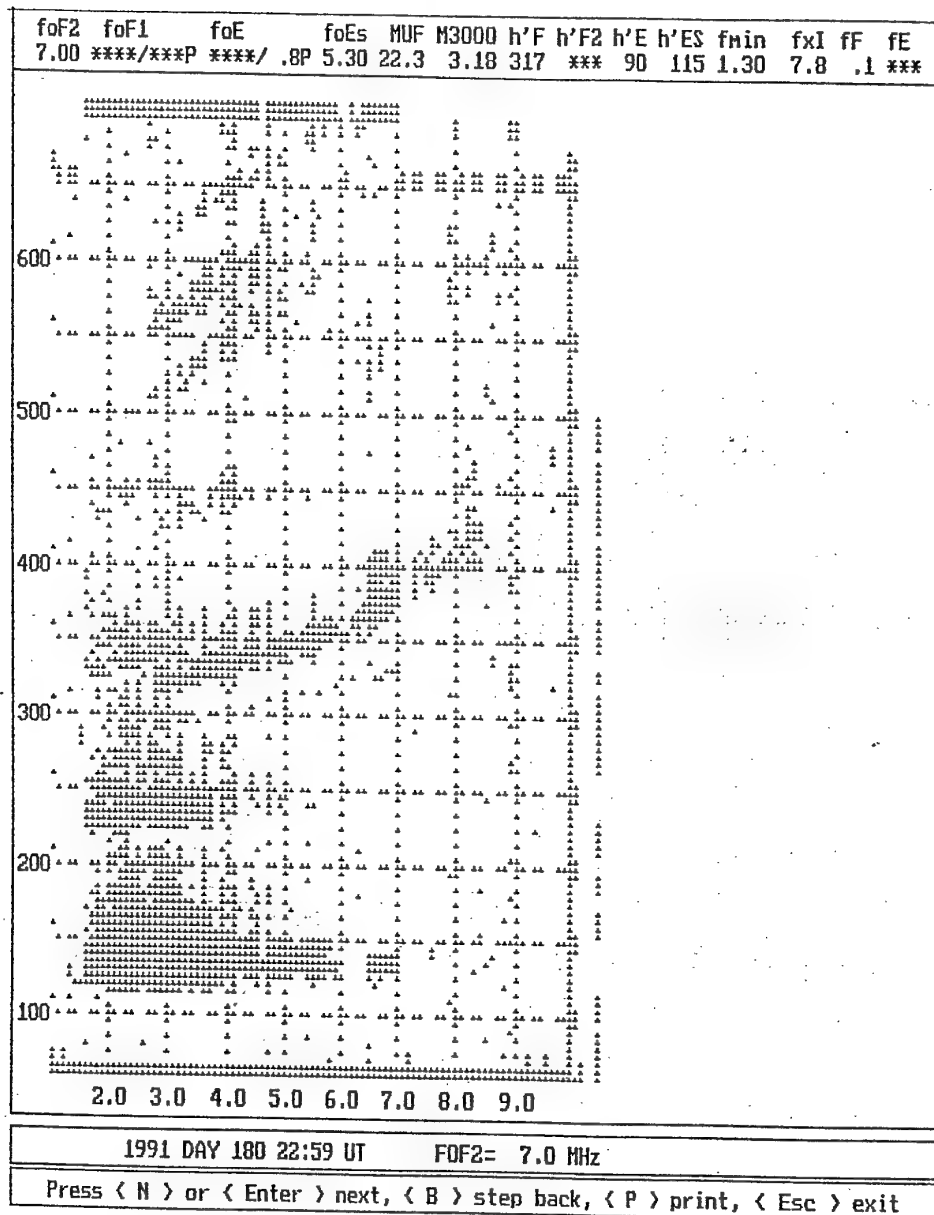


Fig. 4. 29 June 1991, index f

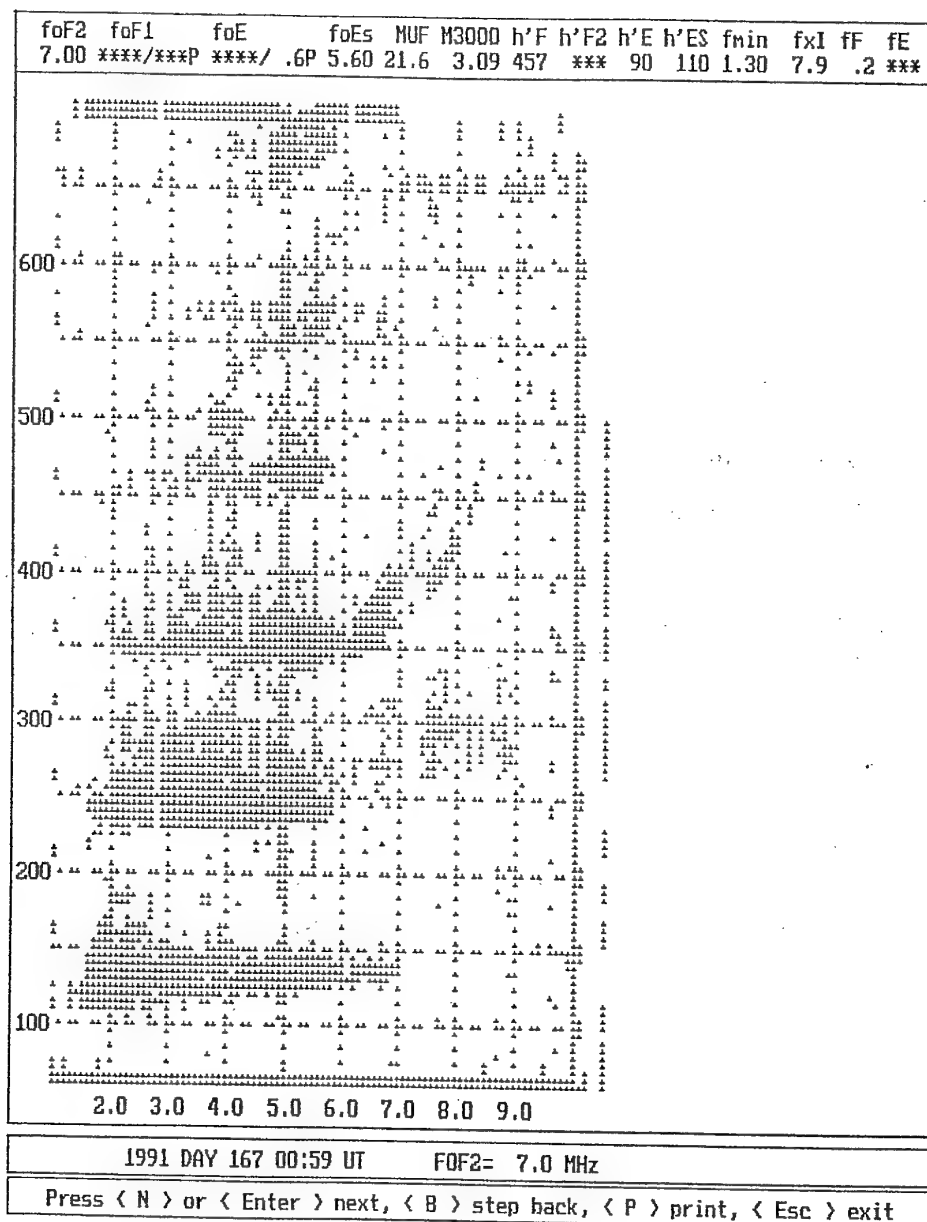


Fig. 5. 16 June 1991, index fBE

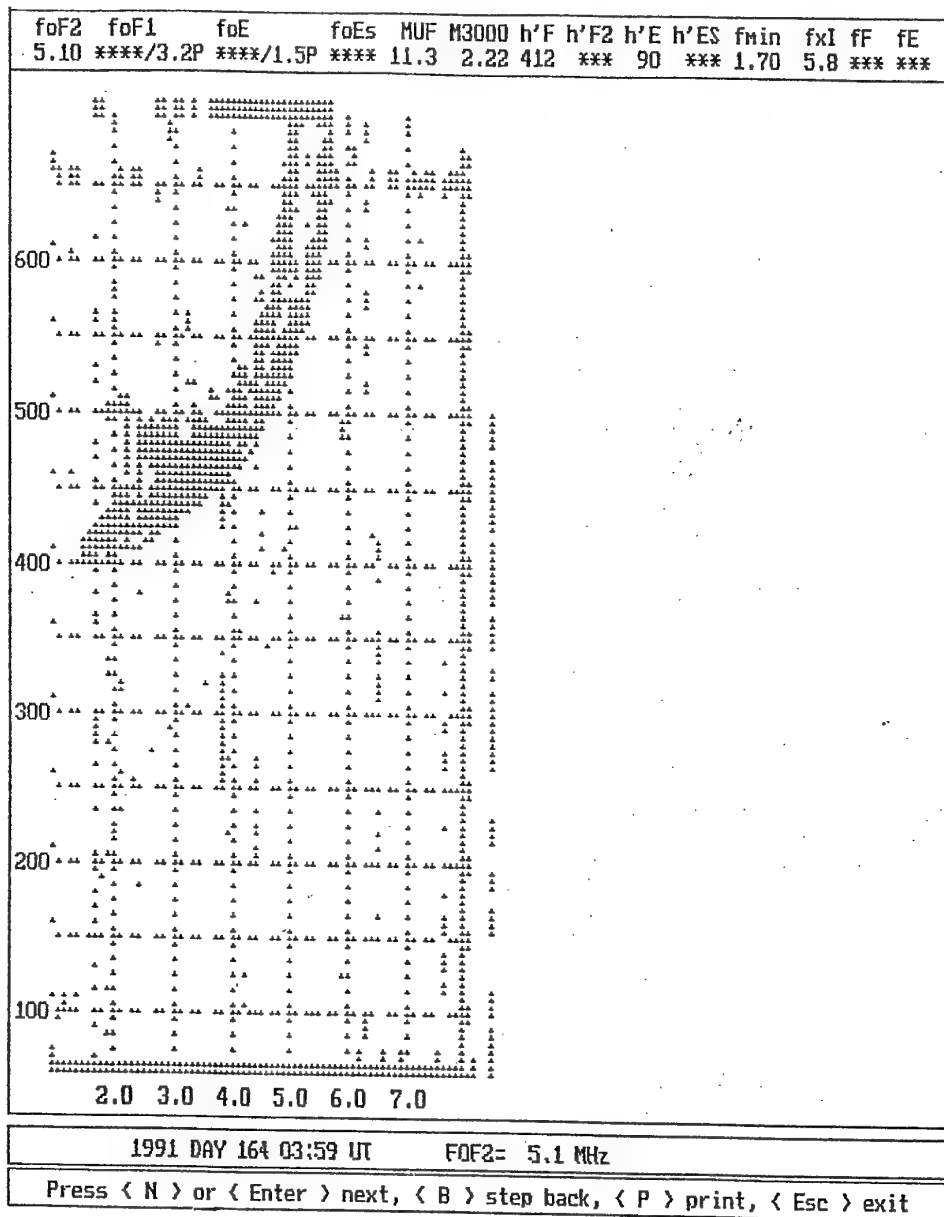


Fig. 6. 13 June 1991, index fr

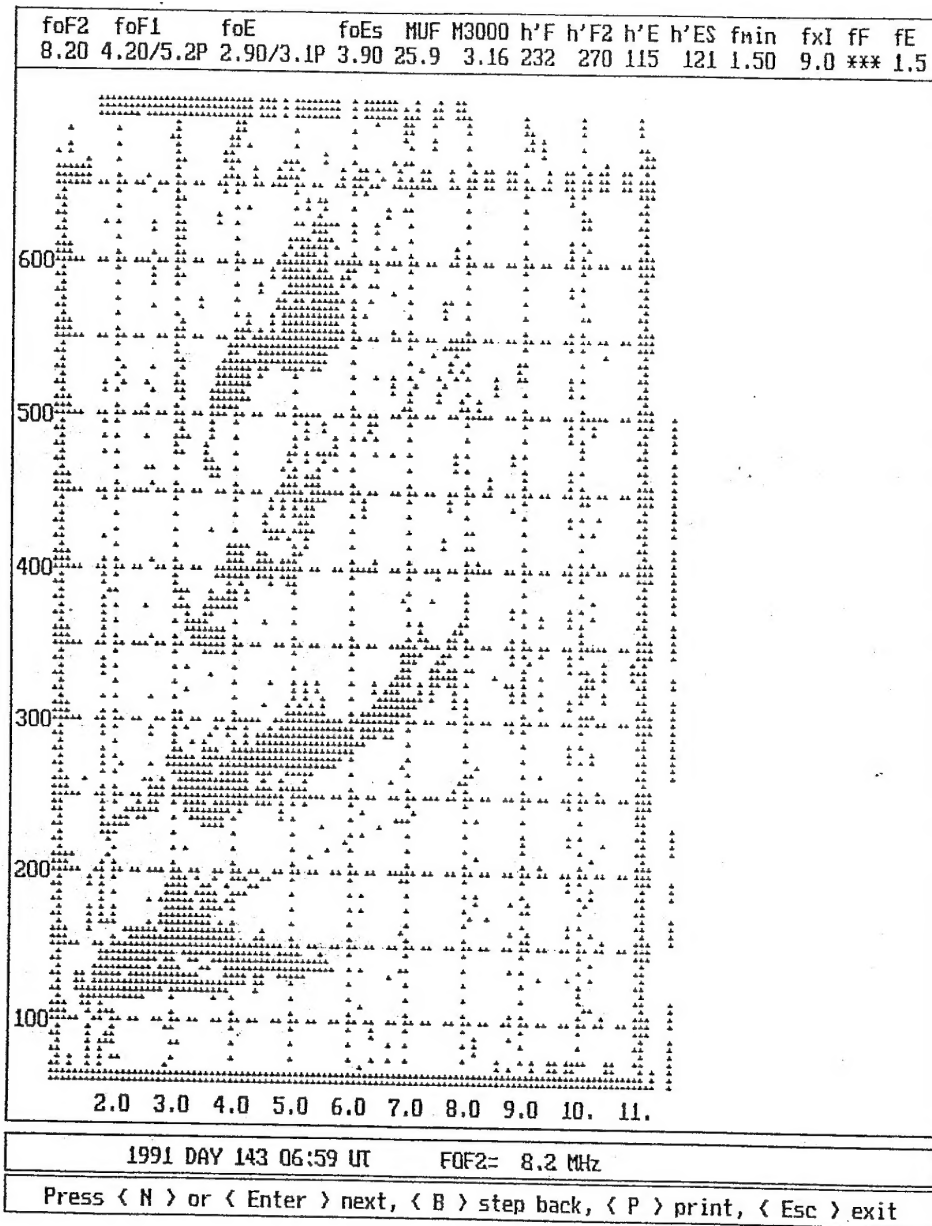


Fig. 7. 23 May 1991, index cr

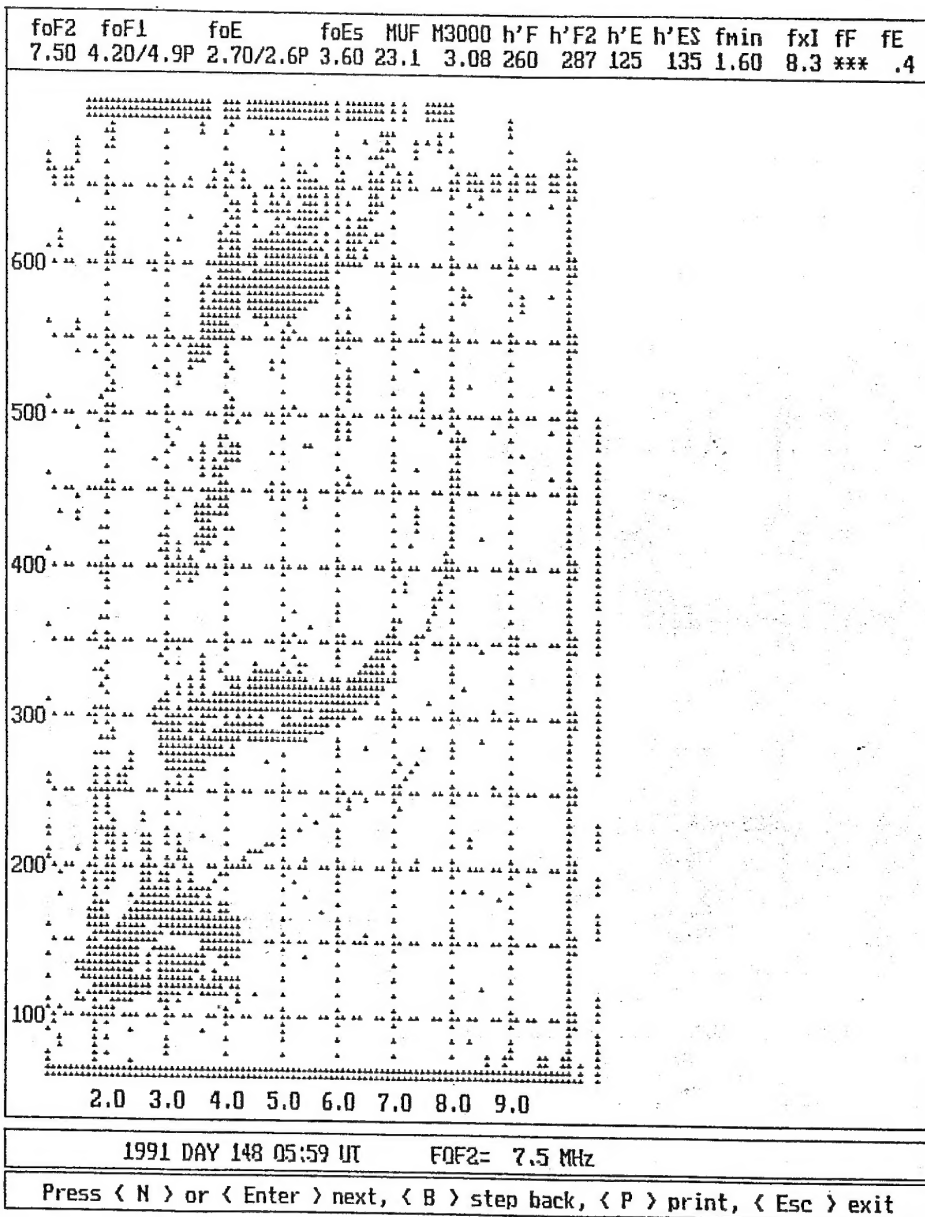


Fig. 8. 28 May 1991, index frE

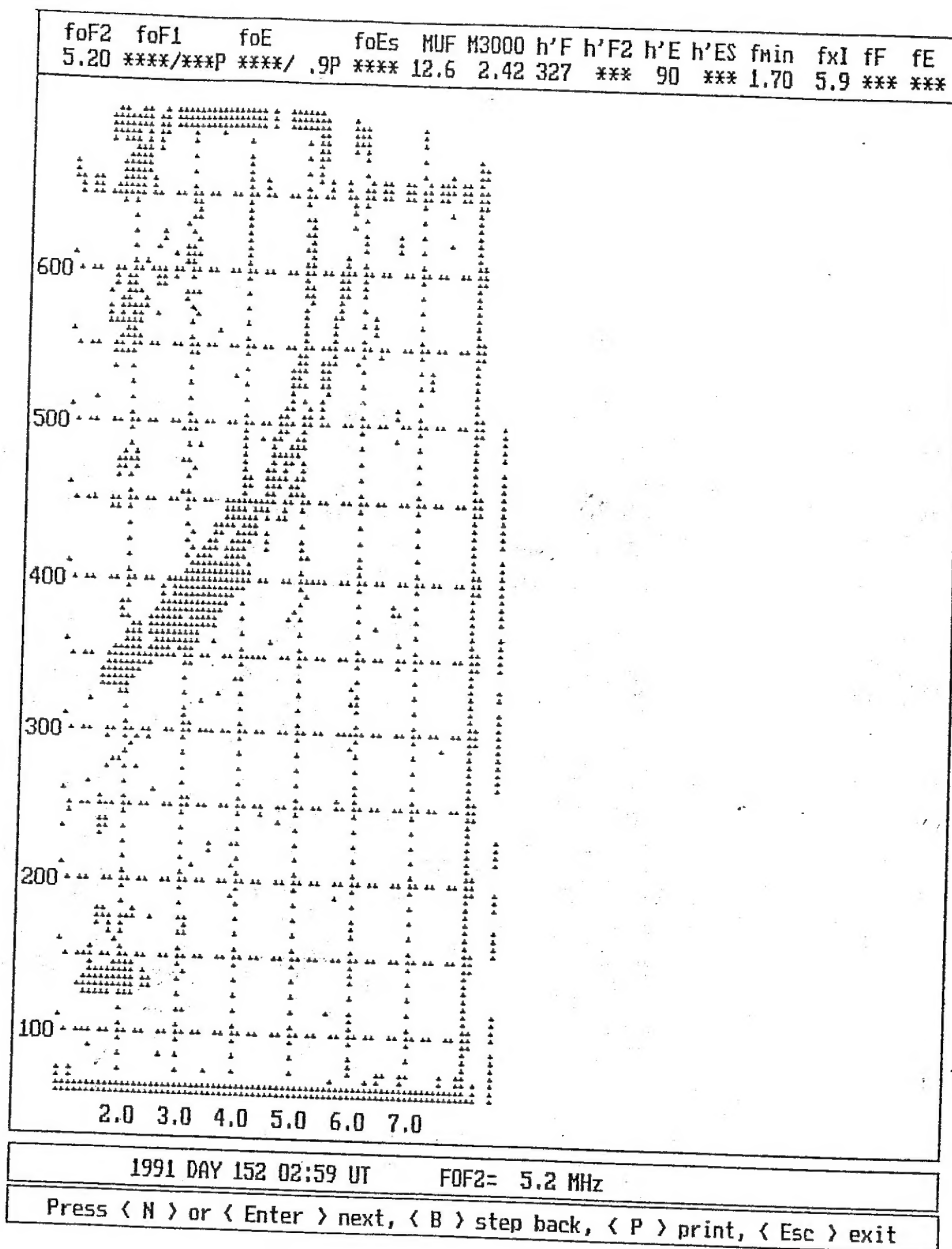


Fig. 9. 1 June 1991, index fw

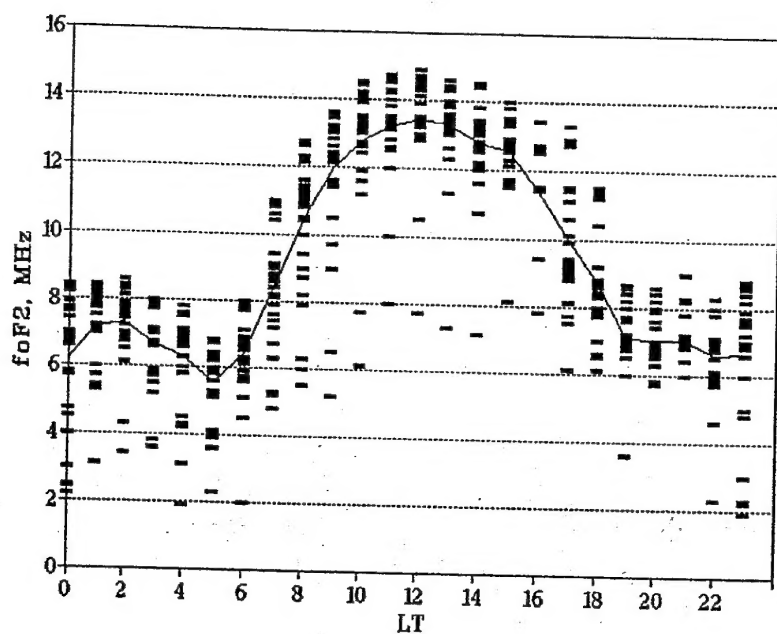


Fig. 10 foF2 values and mean value foF2 for March 1991, Roquetes, Spain.